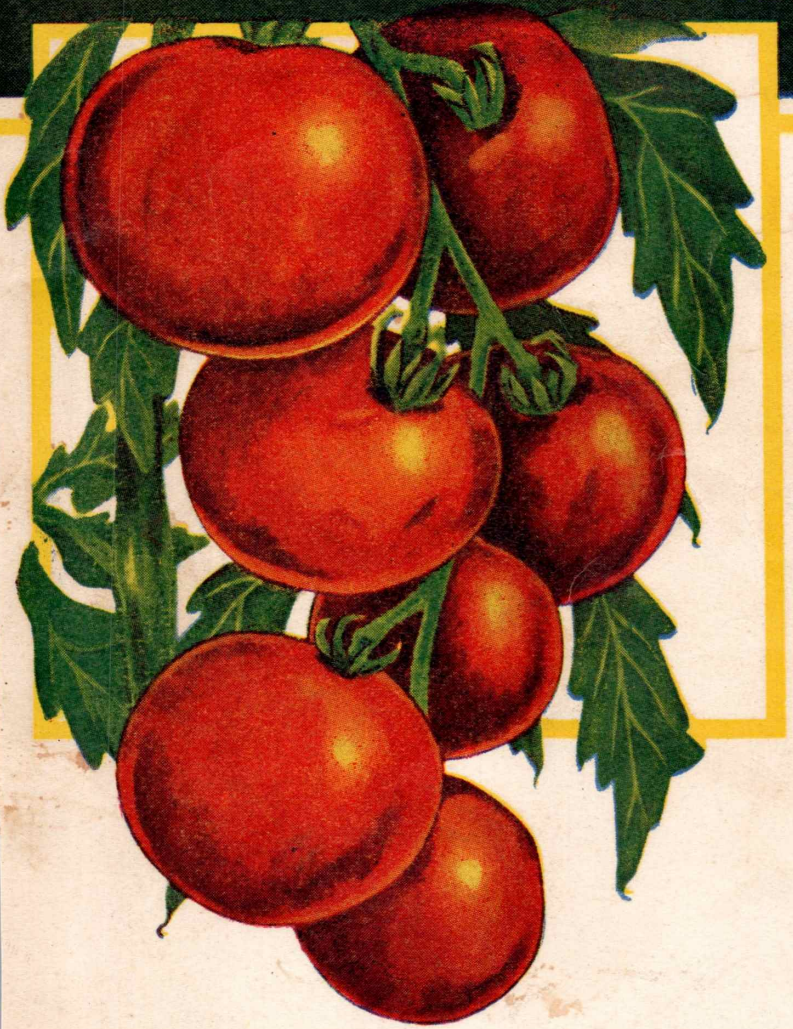
TOMATO DISEASES and PESTS



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DEPT. SCIENTIFIC & INDUSTRIAL RESEARCH
PLANT DISEASES DIVISION : AUCKLAND

TOMATO DISEASES AND PESTS IN NEW ZEALAND AND THEIR CONTROL

by

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Issued under the authority of The Hon. T. H. McCombs,
Minister of Scientific and Industrial Research.

Published by
THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH,
WELLINGTON, NEW ZEALAND

Information Series No. 2

Printed by JOHN McINDOE LTD., DUNEDIN
1949

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INTRODUCTION

TOMATOES are one of the most important and widely distributed vegetable crops in New Zealand. Commercial production is essentially of three types: (1) glasshouse crops grown for spring or late autumn markets, (2) main outdoor crops, and (3) outdoor crops grown specifically for canning, sauce, etc. Approximately 150 acres of tomatoes are grown annually under glass, and 1,200 acres grown in the field. The approximate wholesale value of glasshouse crops is £600,000, while that of outdoor crops is about £480,000, giving a total of £1,080,000 as the value of commercial tomato production in the Dominion. In addition, a large number of home gardeners grow tomatoes for their own use.

Wherever tomatoes are grown in New Zealand they are subject to diseases and pests which, because of their serious effect on yield and market value, are a major factor in crop production. In this bulletin those commonly affecting tomatoes in the Dominion are described, and measures for their control recommended. The bulletin comprises seven major sections dealing with fungous, bacterial, virus and physiological diseases, insect pests, spray and fumigation treatments, and soil disinfection. As control measures vary with the disease or pest concerned, it is necessary to determine the agent responsible before applying a treatment. To assist in identification, descriptions are given in the text and a key is provided at the end of the bulletin (p. 109).

The writers wish gratefully to acknowledge the assistance given by the many officers of the Horticulture Division, Department of Agriculture, who forwarded specimens from different districts and who, from time to time, assisted with field and glasshouse experiments. The Horticulture Division also kindly supplied figures for acreage and crop value of tomatoes in New Zealand. We also wish to thank those many growers throughout the Dominion who co-operated to make disease surveys possible and placed at our disposal facilities for carrying out trials. We are indebted to Mr. P. J. Clark, Dominion Laboratory, for carrying out chemical analyses of spray materials and to the technical staff of the Plant Diseases Division, in particular to Messrs. C. H. Procter and A. J. Webb, who supplied much information used in the preparation of this bulletin. Our thanks are also due to Miss M. J. Dahlberg and Messrs. H. Drake, W. E. Barnard, L. H. Wright, and R. I. Hughes for most of the photographs used as illustrations.

Figs. 70 and 81 are reproduced from the *New Zealand Journal of Agriculture*, Fig. 55 from *Garden Pests in New Zealand and How to Control Them*, by D. Miller, Fig. 61 from the *Agricultural Gazette, New South Wales*, Fig. 73 from *Insects of Western North America*, by E. O. Essiz, Fig. 84 from *Plant Protection by the Aid of Therapeutants*, by G. H. Cunningham, and Fig. 85 from *Bulletin 22 of the Ministry of Agriculture and Fisheries*, by W. F. Bewley, with the permission of the Controller of his Britannic Majesty's Stationery Office.

FUNGOUS DISEASES

FUNGI are primitive plants devoid of the green colouring matter (chlorophyll) present in most other plants. They cannot elaborate their own foods, so must obtain them either from living plants or from decaying organic matter in the soil. Fungi consist of threadlike vegetative growths (collectively called mycelium), from which are produced various types of structures that bear minute bodies known as spores. These spores are the reproductive stage, and in the presence of suitable temperature and moisture they can germinate and produce new infections. Fungi gain entry to plants either through the roots, through injuries, through natural openings and dead tissues, or directly through the epidermis. They spread within the tissues and produce specific symptoms such as wilting, lesions on stems, leaves or flowers, and rotting of fruits. Infection is spread mainly by spores, which are carried by wind, rain, insects and persons working among the plants.

LATE-BLIGHT

Late-blight of tomatoes, caused by the fungus *Phytophthora infestans* (Mont.) de Bary, is one of the most serious diseases with which growers have to contend. The disease is widespread in tomato crops throughout the Dominion, and in the Auckland province often causes up to 50 per cent. loss of crops. If left unchecked the fungus may spread rapidly and eventually ruin the whole crop by damaging leaves, stems and fruits. Although late-blight is more prevalent in field crops, it may become established on crops grown under glass, where considerable damage results. Late-blight of potatoes is caused by the same fungus.

Fig. 1—Late-blight: infection on leaves. × ½.
Photo by L. H. Wright.

Fig. 2 (above)—Late-blight: infection of stem and leaf stalks. Natural size.
Photo by L. H. Wright.

Fig. 3 (right)—Late-blight: infection on tomato stem. × 2/3.
Photo by H. Drake.

Symptoms

The disease may attack plants at any stage after they are pricked out in boxes, and all parts above ground-level may be affected. The first symptoms appear as irregular, greenish-brown to black, water-soaked patches on leaves and leaf stalks (Fig. 1). These areas rapidly enlarge, and during wet weather a white, downy growth of the fungus is produced on undersides of leaves. Infected leaves later become blackened as if damaged by frost. Under moderately warm, wet conditions, infection spreads so rapidly that nearly all leaves are affected and plants may be killed in a few days.

Stem infection frequently occurs, symptoms similar to those on leaves being produced. Lesions 4–6 inches in length and completely girdling stems are commonly observed (Figs. 2 and 3). On fruits, infection takes place usually at or near the stem end and may occur at any stage of development.

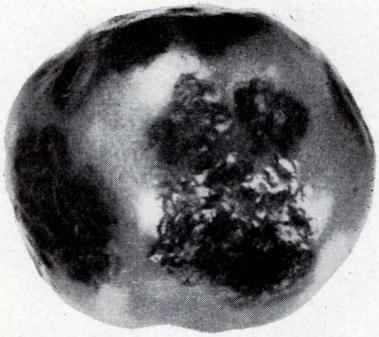


Fig. 4—Late-blight: infection on tomato fruit. × 4/5.
Photo by H. Drake.

The disease first appears as small, greenish-brown, water-soaked areas that rapidly enlarge until the fruit surface may be completely covered (Fig. 4). As the disease progresses, infected patches change from greenish-brown to brown and show definite margins, but generally no visible aerial growth of the fungus is apparent. The surfaces of infected fruits remain firm, and have a wrinkled or corrugated appearance. As the fruits ripen, lesions become darker in colour, and are separated from the normal red tissues by a narrow green margin.

Factors Favouring Infection and Spread

The amount of infection caused by late-blight is dependent on prevailing weather conditions. The most serious losses occur during wet seasons when nights are cool and days moderately warm. When abundant moisture is present, the fungus produces spores in large numbers on undersides of infected leaves. These are splashed by rain or carried by wind to adjacent plants. The spores germinate readily at temperatures between 50° F. and 60° F., but are killed if the atmosphere is dry and temperature above 80° F. After infection takes place, the disease develops most rapidly at temperatures between 70° F. and 75° F. The fungus is carried over from season to season on decaying plant refuse in the soil, and is spread during the growing season from neighbouring infected tomato or potato crops.

Control

Experiments on control of late-blight have shown that the disease can be readily held in check by applications of Bordeaux mixture or Bordeaux substitutes (see pages 83 and 85). Spraying should be commenced before plants are set out in the field or glasshouse. When they have become established, regular applications are necessary during the growing season. After harvesting, all diseased tomato refuse should be collected and burnt. Where possible, tomatoes should not follow potatoes in the field, and it is advisable not to locate these crops in adjacent areas.

VERTICILLIUM-WILT

Verticillium-wilt of tomatoes was first recorded in New Zealand in 1924, but was not known to cause serious damage to crops until 1931–32. During that season it was prevalent in glasshouse tomatoes in the Auckland province, and in field crops at Gisborne. Since then it has occurred in all the main tomato-growing areas in the Dominion, and is at present a major problem to growers. The disease is caused either by *Verticillium albo-atrum* Reink. and Berth. or by *Verticillium dahliae* Kleb., two closely related soil fungi which produce similar symptoms on tomatoes. Verticillium-wilt causes a gradual wilting and ultimate death of plants, and in a severe attack 50–80 per cent. losses have been observed. It is more prevalent in glasshouse tomatoes, but frequently occurs in the field, particularly in autumn crops. Besides tomatoes, the disease attacks potatoes, tobacco, eggplant, cucumber, fat-hen, black nightshade, gooseberry, raspberry and apricot in New Zealand.

Symptoms

The first symptom, which usually appears when plants are at the three to five truss stage, is a slight wilting of leaves at the growing point. In the first few days of the attack, plants may partially recover during the night, but wilting gradually increases until within a week or ten days complete collapse occurs (Fig. 5). Once a plant has collapsed the leaves soon turn brown and the plant dies. Sometimes growing points do not wilt, symptoms being confined to wilting and yellowing of lower leaves and stunting of plants. No external symptoms occur on stems, but on cutting them transversely, the vascular bundles show a light-brown discolouration. This discolouration is confined to the vascular tissues, and usually extends to the top of the plant. When plants become infected before they come into bearing, they do not yield any fruit. After the plant dies, the fungus spreads through the tissues and under favourable conditions grows out to the surface, usually at ground-level, where it produces a white growth and large numbers of spores.

Factors Favouring Infection and Spread

The verticillium-wilt fungus is typically a soil organism and infection can only take place through the soil. It is carried over from season to season by means of thick-walled mycelium and resting spores, which germinate when conditions are favourable and spread through the surrounding soil. The fungus is able to enter the uninjured roots and grow up into the stems, where it invades the water-conducting tissues and causes plants to wilt. In infected soil the disease remains viable for several years. It may be spread to clean ground with infected soil adhering to seedling plants. Potato tubers carrying the disease also act as a source of infection. Plants that received a check during the growing season are usually more susceptible to the disease, and excessive water at the roots aggravates wilting.

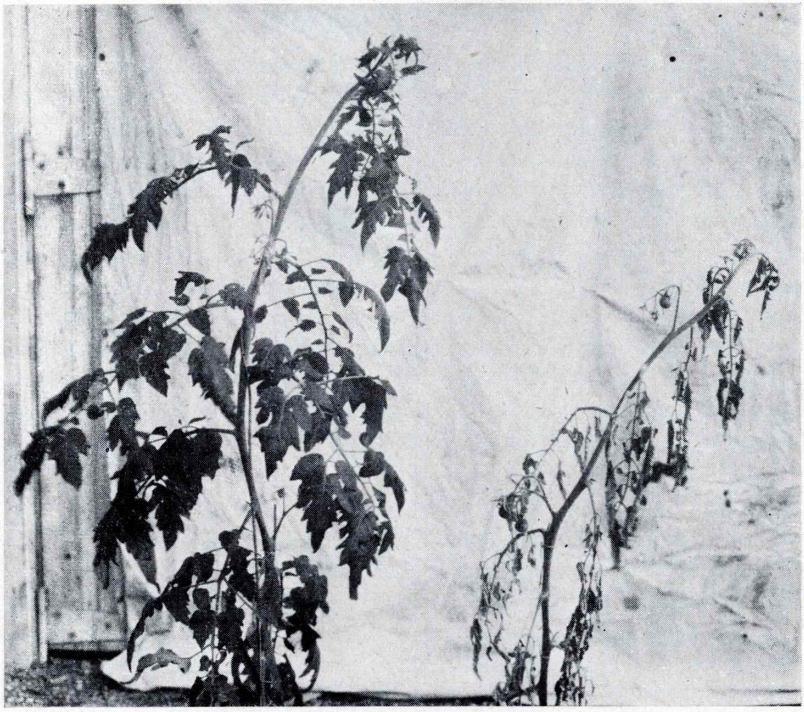


Fig. 5—Verticillium-wilt: on left, healthy plant; on right, infected plant of same age.
Photo by H. Drake.

Control

For control of verticillium-wilt in the field, the following recommendations are made:—

1. Wherever possible avoid growing tomatoes on land which has been in tomatoes, potatoes, eggplants, tobacco or other susceptible host plants during the previous two or three years.
2. Use plants that have been raised either in steam or chemically-disinfected soil (see pages 92–99).
3. Take care that plants receive as little check in growth as possible and avoid excessive watering.
4. Where only a few plants become infected, remove and destroy them by burning. After harvesting, collect and destroy all plant remains.
5. Keep soil free from weeds such as fat-hen and black nightshade which may carry infection.
6. Where wilt becomes general, cultivate thoroughly and mould up the earth at base of plants to encourage formation of new roots. Avoid excessive use of nitrogenous manures.

For control of the disease in the glasshouse the following recommendations are made in addition to those above:—

1. If verticillium-wilt has been present in previous crop, disinfect soil either by steam or chemicals (see pages 92–99).
2. When re-soiling glasshouses, use soil preferably from a field that has been down in grass for a number of years.
3. Where the disease is general throughout the crop, whitewash the glass and give plants a light spraying with water, as this will assist partial recovery.

FUSARIUM-WILT

Fusarium-wilt, caused by the fungus *Fusarium bulbigenum* Cke. and Mass. var. *lycopersici* (Brushi) Wollenw. is a minor disease of tomatoes in New Zealand. It may occur both in glasshouse and field crops. Although at one time reported to be prevalent in this country, the disease has been rarely observed during recent years.

Fusarium-wilt symptoms are very similar to those produced by verticillium-wilt, the two diseases being readily confused. In addition to wilting and gradual death of plants, the disease attacks roots and the base of stems. On infected plants the smaller roots rot away, while brown cankers form on larger roots and underground portions of stems. On cutting transversely through stems, the vascular bundles are seen to be discoloured dark-brown. Discolouration is confined to the bundles and as a rule occurs only in the lower portions of stems.

Fusarium-wilt develops at high temperatures, being most severe between 80° and 90° F. In the glasshouse the disease may be checked by reducing the temperature where possible to as much below 80° F. as is consistent with good growth of plants. In addition, control measures as recommended for verticillium-wilt should be carried out.

SCLEROTINIA-DISEASE

Sclerotinia-disease (also known as stem-rot, stalk-disease and sclerotium-disease) in certain seasons may cause serious losses in tomato crops. This disease, which is caused by the fungus *Sclerotinia sclerotiorum* (Lib.) de Bary, is of world-wide distribution. It was first recorded on tomatoes in New Zealand in 1906, and occurs in every district where this crop is grown. While a small proportion of plants may be attacked every year, the disease occurs in severe form only in certain seasons. Although more troublesome in outdoor crops, it may become a serious problem in glasshouses, particularly in those not heated; over 30 per cent. infection was recorded in a Christchurch glasshouse in 1923.

Symptoms

The first sign of the disease is usually a sudden wilting of the plant when in the four or five truss stage, i.e., just as it is coming into bearing. At some point below the wilted parts there is a light-brown, decayed area on the stem. This area later becomes covered by a white growth, and marks the limit to which the fungus has penetrated (Fig. 6). Infection usually takes place at the nodes and at some distance above the ground, but occasionally plants are attacked at ground-level.

Fig. 6—Sclerotinia-disease: tomato plant in field showing infection near ground-level.
Photo by H. Drake.

The fungus spreads rapidly through the stem tissues, cutting off the food supply, with the result that the plant wilts and dies. The disease usually confines its attack to the stem, the leaves being killed merely by starvation. If the discoloured portion of stem is opened up, it will be found to contain white fungous growth in which are embedded irregularly shaped, black bodies called sclerotia. The sclerotia vary in size from approximately $\frac{1}{4}$–$\frac{1}{2}$ inch in length (Fig. 7). They are hard and tough, and on being cut the interior is seen to be white. In normal seasons when sclerotinia-disease is not severe, infected plants are usually found scattered throughout the field, but when the disease is prevalent large patches may become infected.

Host Range

Besides tomatoes, the disease attacks a wide range of plants, being recorded in New Zealand on 60 different hosts. It frequently causes losses on such crops as cabbages, artichokes, lettuce, French beans, potatoes, and blue lupins.

Factors Favouring Infection and Spread

The sclerotia are resistant to heat and cold, drought and moisture, and are able to remain viable in the soil for several years. In the spring and early summer, under favourable conditions of temperature and humidity, sclerotia germinate and produce light-coloured, stalked, cup-shaped bodies (Fig. 8). From these are ejected spores which are carried by air-currents to neighbouring plants. High humidity and wet soil conditions are factors most favourable for development of these cup-shaped bodies and for germination of spores. The optimum temperature for growth of the fungus lies between 60° F. and 70° F. Sclerotia from infected crops other than tomatoes may serve as a source of infection.

Fig. 7.
Sclerotinia-disease: sclerotia lining the pith cavity of tomato plant. × 2/3.
Photo by H. Drake.

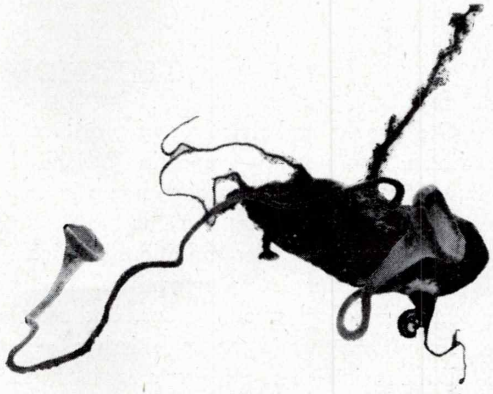


Fig. 8—Sclerotinia-disease: cup-shaped fruiting bodies growing out of sclerotia. × 2.
Photo by H. Drake.

Control

In the Field.

Plants should be well spaced, and judicious pruning of lower leaves practised. The lowering of humidity resulting from greater air circulation and better penetration of sun's rays will check germination of spores and consequently lower infection. The ground between plants should be well worked, and all weeds and other cover removed. Thorough cultivation is one of the most important factors in keeping down infection.

Care should be taken not to introduce the disease with lupin seed for cover crops. Lupin plants should be examined for presence of the disease before digging in. All diseased plants (both tomatoes and other crops) should be removed immediately they are seen, and care taken that sclerotia are not allowed to fall to the ground. Infected plants should be burnt and not piled up in heaps or left on headlands.

In the glasshouse. As in the field, the lower leaves should be pruned and soil well cultivated. Humidity should be kept down by giving as much ventilation as possible, and by avoiding excessive watering. Directly the disease is observed in the house, all infected material should be removed and destroyed. To prevent the disease from carrying over to the next season, soil should be disinfected. This is best done by steam (see page 92), but where facilities for steaming are not available, treatment with formalin solution 1–50 is recommended (see page 96).

GREY-MOULD

Grey-mould or botrytis-rot of tomatoes is usually a disease of minor importance in New Zealand. It is caused by the fungus *Botrytis cinerea* Fr., a common wound parasite on many plants, particularly when they are growing under conditions of high humidity and moderate or low temperatures. The disease is mainly one of glasshouse crops, but occasionally it occurs on tomatoes in the field. It has been observed in all the main tomato-growing areas in the Dominion, but as a rule is found only in autumn or late-autumn glasshouse crops. When conditions are favourable for its development, grey-mould may cause damage to stems, fruits and flowers. It is sporadic in occurrence and only occasionally of economic importance.

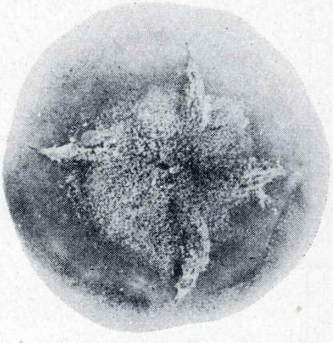


Fig. 10—Grey-mould: rot on green tomato fruit. × ¾.
Photo by M. J. Dahlberg.

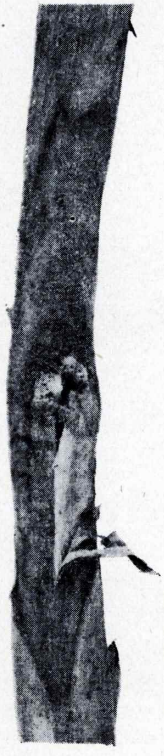


Fig. 9—Grey-mould: infection on stem of tomato plant. Nat. size.
Photo by L. H. Wright.

Symptoms

The fungus becomes established on plants through leaf scars and any damaged or dead tissues. On stems and leaves are produced water-soaked, greenish-brown lesions which soon develop greyish-brown mycelium and spore masses characteristic of the disease (Fig. 9). The fungus spreads rapidly through the tissues, in some cases extending 3–4 inches and completely girdling the stem, with resultant wilting and death of all parts above the lesion.

On fruits, infection may occur through the stem end, the blossom end, or growth cracks. Decay progresses rapidly, lesions becoming slightly sunken, water-soaked, greyish-green in colour with a definite margin (Fig. 10). Spore masses similar to those on stems are formed in the centre of lesions, or where the skin has been ruptured.

Another type of symptom sometimes occurs on fruits as small, white, circular, superficial ring-spots about $\frac{1}{8}$–$\frac{1}{4}$ inch in diameter (Fig. 11). This form of the disease is known as water-spot or ghost-spot. It occurs when the fungus, which has penetrated the skin during periods of high humidity, dies out with the advent of drier conditions. No further damage to fruit results.

Grey-mould occasionally attacks the calyces of flowers, where typical lesions and spore masses are formed. The blossoms wither and die and fruit development is prevented.

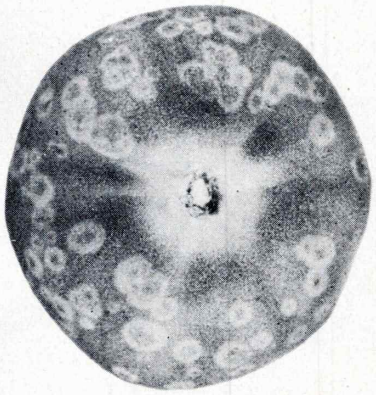


Fig. 11—Grey-mould: water-spot symptoms on tomato fruit. Natural size.
Photo by R. I. Hughes.

Control

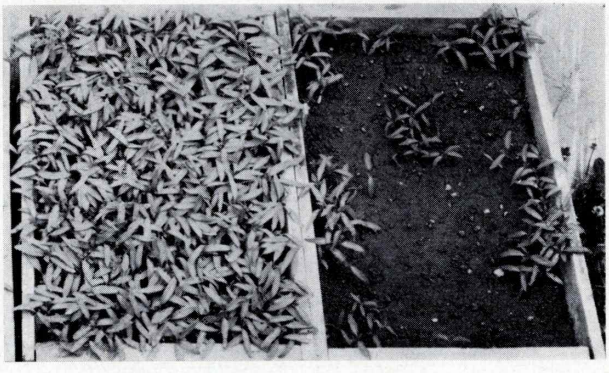
Infection with grey-mould only occurs through injuries or dead tissues, and under conditions of high humidity. Control measures, therefore, should be based mainly on careful methods of pruning and regulation of ventilation to reduce humidity. Plants should be adequately spaced and judicious pruning of lower leaves practised to allow free circulation of air. Pruning operations should be carried out carefully so that laterals and leaf stalks are removed without leaving any stumps. All infected material together with dead or yellowing tissues, both on plants and on the ground, should be removed and burnt. Spray plants with Bordeaux mixture or Bordeaux substitutes as for late-blight. (See page 83.) Excessive watering in the glasshouse should be avoided.

DAMPING-OFF

Tomato seedlings are particularly susceptible to this disease, and where measures have not been taken for its control, growers often find that large numbers of seedlings have collapsed and died almost overnight. This disease has been prevalent in New Zealand for a number of years, being first recorded in 1924. It occurs in all soils throughout the Dominion. In this country damping-off is caused either by *Pythium ultimum* Trow. or by *Corticium solani* (Prill. and Delacr.) Bourd. and Galz., the former being the more prevalent. The disease is confined to seedlings, plants being safe from attack once they have become established after transplanting.

Symptoms

Seedlings are susceptible to attack by damping-off fungi from the time seeds germinate until some time after plants have been pricked out. Damage to seedlings is of two types. When infection is severe, a large number may be attacked and killed before they reach the surface of the soil (Fig. 12). This type, known as pre-emergent damping-off, is frequently the cause of inferior stands which are sometimes attributed to poor germination of seed. In many cases, however, seedlings become infected after they emerge. These show light-brown, water-soaked lesions at, or just above, soil level. The stems become constricted, and finally plants fall over (Fig. 13). This type of infection, known as post-emergent damping-off, usually occurs in small patches which gradually increase in size until plants reach the stage at which they are no longer susceptible. Often infected seedlings are not killed at once, but roots and stems are damaged. Such plants remain stunted, and usually do not survive transplanting. Infection may occur on pricked-out plants several inches tall, but attack at this stage is not common.



A B

Fig. 12—Damping-off.

Box A, seedlings grown in soil treated with formalin. **Box B, untreated soil showing result of heavy pre-emergent infection.**

Photo by H. Drake.

Fig. 13—Damping-off: showing post-emergent infection of seedlings.
Photo by H. Drake.

Control

In dealing with a disease such as damping-off, where infection may spread rapidly through the soil from plant to plant, it is essential that any treatment applied should give complete control. Experiments have shown that the only efficient method of controlling damping-off is by disinfection of soil. This should be done prior to sowing the seed, either by steam or by the application of chemicals such as formalin or chloropicrin (see pages 92–99). Seed-boxes used for growing tomato seedlings should also be disinfected. After any of the above treatments, care should be taken to avoid recontamination of the soil.

FOOT-ROT

Foot-rot of tomatoes, caused by the fungus *Phytophthora cryptogea* Pethybr. and Laff. is a disease of minor importance in New Zealand. It was first recorded on young plants from a glasshouse at Timaru in 1938, where approximately 13 per cent. of plants were infected. Since then the disease has been found at Auckland, Christchurch, and Nelson. Infection may occur on plants either in boxes or after they are set out in the glasshouse.

Symptoms

The disease is usually apparent when plants are about 6 inches high, but may not occur until they are 12–18 inches high. It becomes evident as a brown discolouration of the stem tissues at, or just below, ground-level. These

tissues become shrivelled, leaflets curl upwards at the edges, the stem collapses and finally the plant dies (Fig. 14). If an infected plant is lifted from the soil, the primary root system is found to be decayed. When young plants are attacked, progress of the disease is usually rapid, but on older plants adventitious roots are often formed above the point of infection. Such plants may recover if conditions of temperature and moisture are not favourable for development of the fungus.

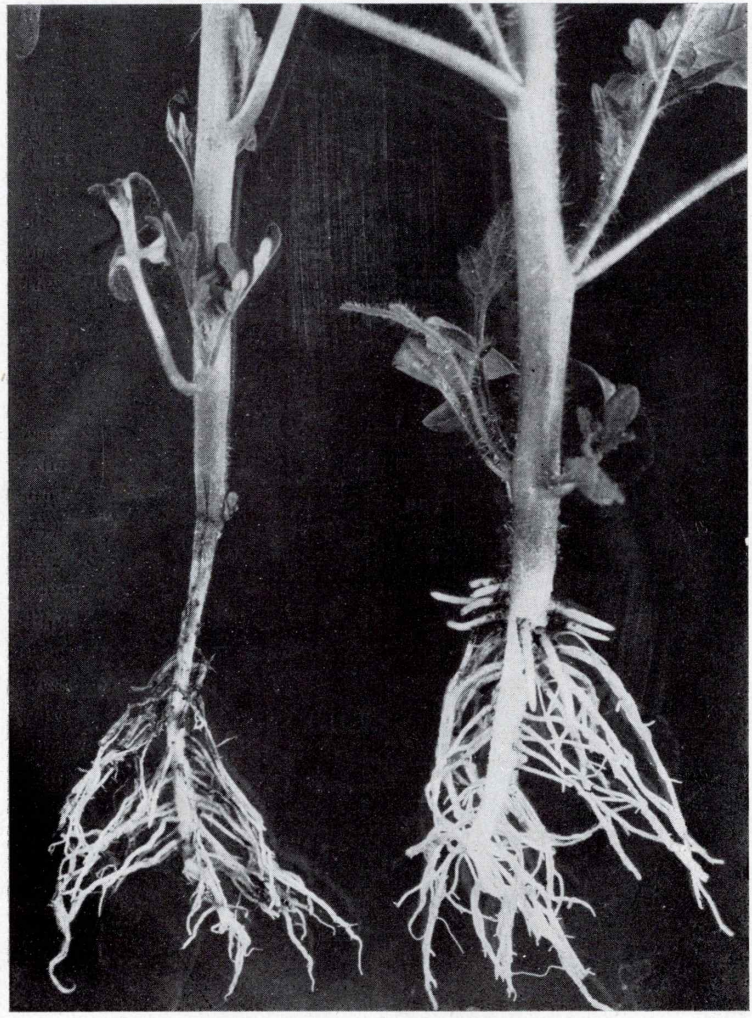


Fig. 14—Foot-rot: infected plant on left, note constriction and decay of stem at ground-level. Healthy plant same age on right.

Photo by H. Drake.

Control

The disease is carried over from season to season in the soil and is favoured by wet soil conditions and inadequate drainage. Disinfection of soil in boxes and in the glasshouse either by steam or by the application of chemicals, as recommended for damping-off and verticillium-wilt, is the most efficient method of control (see pages 92–99). Excessive watering of plants should be avoided and adequate drainage maintained.

LEAF-MOULD

Leaf-mould is one of the most troublesome diseases of glasshouse-tomatoes in New Zealand. It is of world-wide distribution and was first recorded as causing losses in tomato crops in the Dominion in 1896. Leaf-mould is caused by the fungus *Cladosporium fulvum* Cooke, and is confined to tomatoes. In this country is is of economic significance mainly in glasshouse crops where all plants may become severely infected. However, in some seasons leaf-mould causes losses in outdoor crops, particularly dwarf varieties, in northern districts.

Symptoms

Leaf-mould mainly affects the foliage, although blossoms and fruit trusses are also attacked. The disease appears first as small downy patches on the undersides of leaves. Under humid conditions these areas rapidly enlarge and the colour changes to pale-buff and finally to a tawny-brown (Fig. 15). As lesions enlarge, the margins advance as downy white bands, and the centres assume a velvet-like appearance. Development of lesions on the undersides of leaves is accompanied by formation of yellow areas on the corresponding upper surfaces. Infection often takes place at many points on a leaf, and as the spots enlarge they coalesce. Severe infection soon causes death of leaves. Lower leaves are usually the first to show infection and from these the disease gradually spreads upwards. Infected blossoms show similar symptoms, and lesions may occur either on calyx or ovary. Diseased flowers usually fail to develop. Fruit stems may also be attacked by the leaf-mould fungus. Fruit infection has not been recorded in New Zealand.

The extent of damage caused by this disease depends largely upon the stage at which infection occurs. If plants become infected before fruit is formed, considerable loss of crop may result. If infection is delayed until the main portion of crop is about to ripen, fully-grown fruits are not affected, but younger fruits will not attain full size. Flower trusses developing from this time onward usually fail to produce marketable fruit. When infection takes place towards the end of the season, the disease has little effect on the crop.

Factors Favouring Infection and Spread

Spores of the leaf-mould fungus are produced in large numbers on the undersides of leaves, and are readily carried by air currents, watering and contact with plants. The spores in a dry condition can remain viable for at least 12 months. They settle on walls and window sashes and thus can be carried over to plants of the succeeding crop. Occasionally the spores may also be carried on the seed. The two main factors governing infection are humidity and temperature, the former being of greater significance. The fungus most readily infects at relative humidities above 90 per cent. and at temperatures of 72° F. to 80° F.

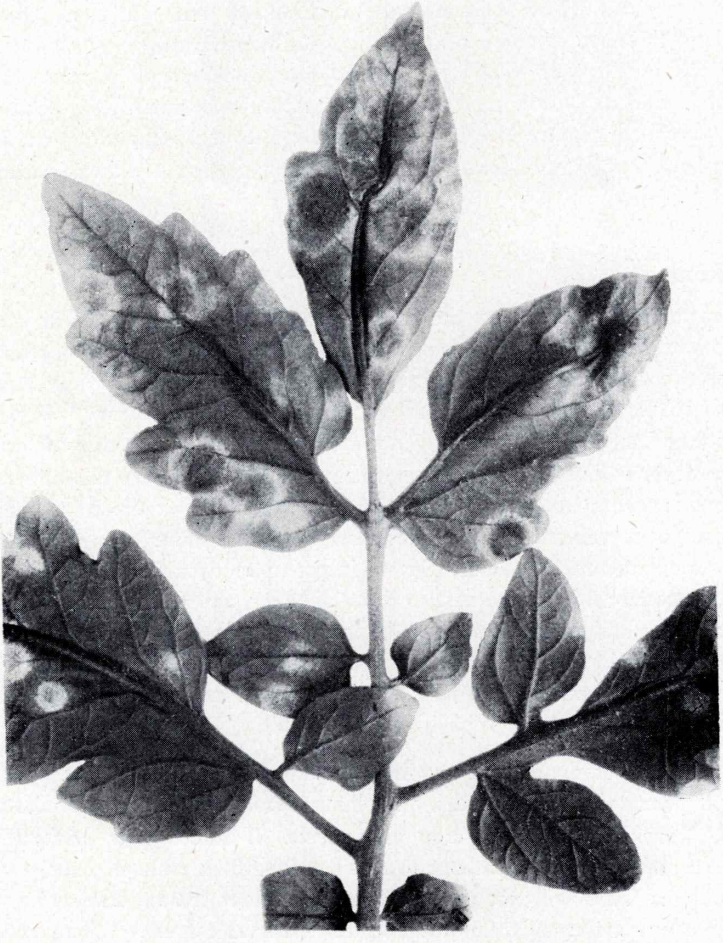


Fig. 15—Leaf-mould: infection on underside of tomato leaves. × 4/5.
Photo by H. Drake.

Resistant Varieties

Some varieties of tomatoes have shown resistance to leaf-mould infection. In 1940, seed of several resistant varieties was received for trial in New Zealand. In preliminary glasshouse experiments the variety Vetomold proved to be completely resistant to the disease and was also suitable for commercial use in New Zealand. In the 1941–season, Vetomold was successfully grown by many growers throughout the Dominion. During the 1942–43 season, however, it was found that a strain of leaf-mould had developed to which Vetomold was not resistant, and consequently the seed was withdrawn from distribution. Further resistant varieties are being introduced and breeding work carried out in an attempt to produce varieties resistant to strains of leaf-mould present in this country.

Control

Efficient control of leaf-mould is difficult to obtain unless accompanied by some regulation of the humidity in the glasshouse. To check infection and development of the disease, the relative humidity should be kept below 90 per cent., the temperature as much below 72° F. as is practicable, and excessive watering avoided. As much ventilation as possible, consistent with maintenance of an even temperature, should be given on all occasions. Free circulation of air between plants assists in keeping down local humidity, and this is aided by judicious pruning of lower leaves and by avoiding close planting.

Experiments on control by spraying showed that of the materials tested, Shirlan A. G. at a concentration of 3 lb. to 100 gallons of water gave consistently the best control of leaf-mould. It is recommended that plants be sprayed periodically with Shirlan A. G., commencing soon after they are set out and before the disease appears (see page 85).

SEPTORIA LEAF-SPOT

Symptoms

Septoria leaf-spot disease, also known as septoria-spot, or septoria-blight, is caused by the fungus *Septoria lycopersici* Speg. and was first recorded in New Zealand in 1906. In occurs on field-grown plants in all the main tomato-growing areas, but is less prevalent in Auckland than in southern districts. In seasons when temperatures are moderate and relative humidities high, this disease may cause considerable losses in some districts, but it is usually not a serious disease in New Zealand.

Septoria leaf-spot may occur on plants at any stage after they are set out in the field, but infection usually takes place some time after plants have commenced to set fruit. The disease appears first on older leaves near the ground as numerous, small, circular, water-soaked spots about one-sixteenth inch in diameter. These spots later become brown at the edges with greyish-

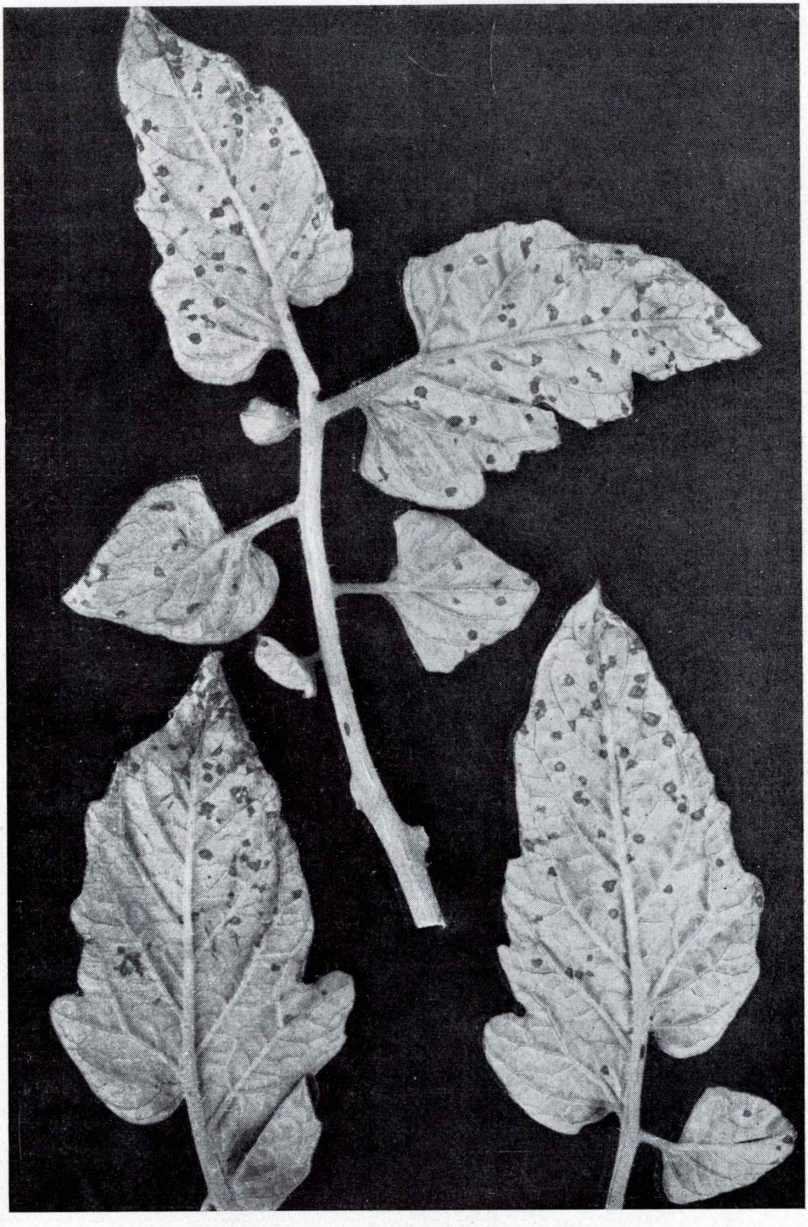


Fig. 16—Septoria-spot: infection on leaflets. × 4/5.

Photo by H. Drake.

white centres, in which are produced minute, black fruiting bodies containing large numbers of spores. Spots may attain a diameter of $\frac{1}{8}$–$\frac{1}{4}$ of an inch (Fig. 16) and often coalesce to form dead patches on the leaves. Where spots are numerous, leaves eventually die and fall from the plant. The disease gradually spreads to the upper leaves, and where infection is severe there is a progressive loss of foliage, and plants may fail to mature their fruits. Owing to loss of foliage on severely infected plants, fruits are liable to be damaged by sun-scald. Septoria leaf-spot is mainly a disease of the leaves, but in a severe attack, similar symptoms to those described above may occur on stems (Fig. 17) and calyces. Fruit infection has not been observed in New Zealand.

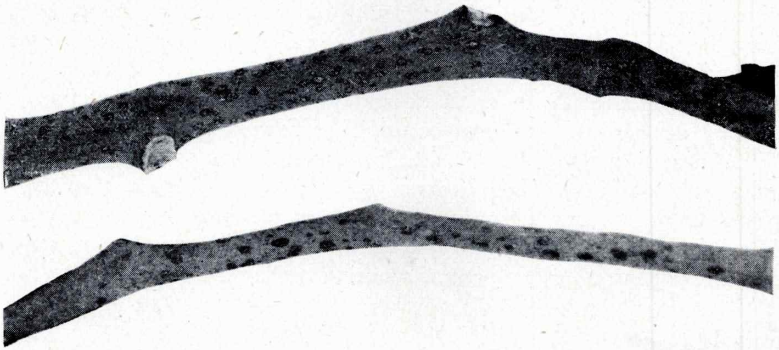


Fig. 17—Septoria-spot: infection on stems. Natural size.
Photo by H. Drake.

Factors Favouring Infection and Spread

The disease overwinters on the remains of infected tomato plants in the soil, and the first infection results from spores produced on such material spreading to lower leaves of plants. After first lesions are formed, abundant spores are exuded in gelatinous tendrils from the black fruiting bodies, and these are splashed by rain or carried by insects to other leaves. The fungus is most active at temperatures ranging from 60° F. to 80° F. and during periods of high humidity and abundant rainfall.

Control

Rotation of crops and destruction by burning of all tomato refuse from an infected area should be carried out. The disease is readily controlled by the standard spray treatments recommended for late-blight, i.e. Bordeaux mixture or Bordeaux substitutes (see pages 83 and 85).

PHOMA-ROT

Phoma-rot of tomato fruits was first recorded in New Zealand in 1939, but had been observed for a number of years prior to that date. The disease is caused by the fungus *Phoma destructiva* Plowr., which is a wound parasite that attacks fruits only through cracks or injuries on the skin surface. It is usually of little economic importance, but is troublesome in some seasons on fruit of late crops with the advent of wet, cold weather conditions during April and May.

Symptoms

The fungus produces a rot on both green and ripening fruits, and first appears as small, irregular, light-brown, depressed areas often at or near the stem end. These rapidly enlarge to a diameter of 1–1½ inches, become sunken, leathery, dark-brown to black with lighter brown margins (Fig. 18). Minute black pustules later develop on the infected areas, and these contain large numbers of spores by which the fungus is reproduced. The underlying diseased tissues are brown or black and remain firm until infection with secondary soft-rotting organisms occurs. The fungus also develops on dead or dying leaves at the base of plants, producing irregular, dark-brown areas with zonate markings. These areas may coalesce to cover most of the leaf surface. During wet weather, masses of spores are exuded from pustules on infected fruit and leaves, and are splashed to other fruits in the vicinity, or are carried by insects or by persons working among the plants.

Control

Phoma-rot is carried over from season to season by spores produced on decaying tomato refuse in the soil. Crop rotation should be practised, and destruction by burning of all plant remains should be carried out after fruit is harvested. In order to avoid spreading the disease in a crop, it is advisable, where possible, not to pick fuit when plants are wet. Plants should be sprayed periodically with Bordeaux mixture or Bordeaux substitutes, as recommended for control of late-blight (see pages 83 and 85).

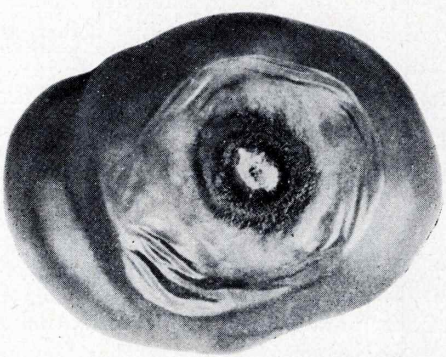


Fig. 18—Phoma-rot: tomato fruit showing advanced stages of infection. Natural size.
Photo by H. Drake.

BACTERIAL DISEASES

Of the three bacterial diseases included here, tomato-canker and tomato-speck can at times cause serious crop losses. The former is a major disease of tomatoes in New Zealand. However, the causal organisms are readily transmitted and there always exists the possibility of widespread outbreaks. Unlike the majority of fungous and insect diseases, they cannot be controlled by therapeutants alone, and growers should regularly take the additional precautions given in this section.

TOMATO-CANKER

Tomato-canker, caused by the bacterium *Xanthomonas michiganensis* (Smith) Dowson, is world-wide in distribution. It was first found in New Zealand in 1936 and since then has been recorded from all tomato-growing districts. The disease is regularly found on staked varieties in glasshouse and field crops from November to March, being recorded from glasshouses in the early half of this period. It is usually confined to a few plants, though in recent years there are records of losses of 30 per cent. or more in glasshouse and field crops.

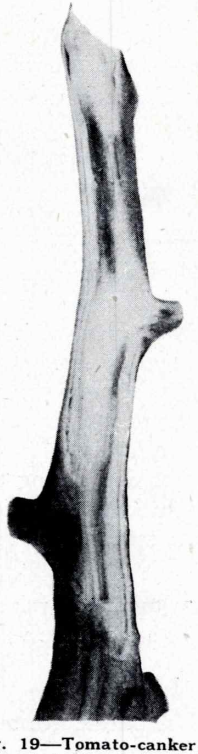


Fig. 19—Tomato-canker: early stem infection, showing dark staining of vascular area and of pith. × ½.
Photo by L. H. Wright.

Symptoms

Young plants are frequently infected and may wilt and die, or remain small and often malformed. Symptoms may not be observed until after infected seedlings are transplanted in glasshouse or field. In older plants the first symptoms are a wilting of portions of the lower leaves, or leaflets on one side of the lower leaves. Affected leaves turn brown and die, but remain attached to the plant. The stem is often bent and malformed. Progress of symptoms to upper parts of plants is slow and several weeks may elapse before all foliage is affected. Fruit setting is reduced, or where satisfactory the fruits do not fully develop. Sometimes immature fruits or lower trusses drop.

In the early stages of infection, stems do not show superficial symptoms. The organism first attacks the tissues just within the cortex near the base of the stem (Fig. 19). With increasing age the outer tissues are destroyed and the stem shrinks and splits longitudinally. Internally, the stems are stained light-brown along the infected zone and the pith becomes shrunken and dark-brown in colour. The early stem and foliage symptoms are similar to those caused by verticillium-wilt (see page 7).

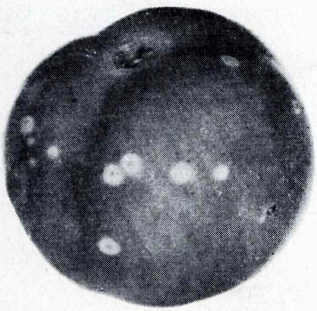


Fig. 20—Tomato-canker: pustules on ripe fruit. × 4/5.
Photo by L. H. Wright.

Fruits from both glasshouse and field crops occasionally show typical white spots about one-eighth inch in diameter (Fig. 20). The centre is a raised, rough pustule surrounded by a white halo which persists through maturing and colouring of fruit. The pustules usually do not extend deeply into the flesh of the fruit, but pulp and seed can be readily contaminated by the tomato-canker organism.

Factors Governing Spread of Disease

The disease is readily transmitted by seed obtained from infected fruit, and outbreaks usually originate from this source. In seedling-boxes or in a crop the causal organisms are readily transmitted by irrigation, cultivation or pruning. Symptoms may not be observed in seedling plants prior to planting out and these then provide sources of further infection in glasshouse or field. Consequently, early recognition of the diseased condition and removal of infected plants are necessary for maintenance of a healthy crop. The practice of cutting or pinching out laterals often transfers sap and canker organisms to healthy plants, whereas breaking off laterals lessens this possibility.

Soil may be contaminated by organisms left in soil from the previous crop, in remains of previous crop, or in seepage or irrigation water from an infected area. The organisms can remain viable in soil for three years, and plants set out in infected soil within this period are readily infected through root injuries arising during transplanting or cultivation. The causal organism in soil can be killed by various disinfection methods, but the cost usually restricts such treatment to soil for seedling-boxes and to limited areas such as glasshouses.

Tomato-canker primarily affects the vascular system, and hence spray materials are of little value once the disease has become established.

Control

1. Use disease-free seed or disease-free plants. Seed should be saved only from disease-free crops and pulp should be acid treated (see page 78). Dry seed of uncertain source should be treated with acidulated mercuric chloride (see page 78).

2. Use clean soil for raising plants, or disinfect soil by steam, formalin or chloropicrin (see pages 92–99).
3. Do not plant in soil which, within three years, has carried infected plants.
4. Rogue out and burn infected plants. Do not replant.
5. Break off rather than cut or pinch out laterals.
6. As a precaution against spread of infection, plants should be sprayed with a copper spray material according to schedule for late-blight (see pages 83–85).

TOMATO-SPECK

This bacterial disease, caused by *Bacterium tomato* (Okabe) Magron, was first found in New Zealand in 1944. In this instance it caused serious loss of young plants in a crop of Tatura dwarf variety raised from imported seed. The disease has not become widespread in this country, but in the United States of America is of economic importance.

Symptoms

Tomato-speck forms on leaves small, dark-brown, irregular spots not more than one-eighth inch in diameter (Fig. 21). They are dry and rough in appearance and are surrounded by narrow yellow halos. Infection often follows along the veins, forming long, narrow streaks. Usually spots are extremely numerous and destroy the dark-green appearance of the leaf.

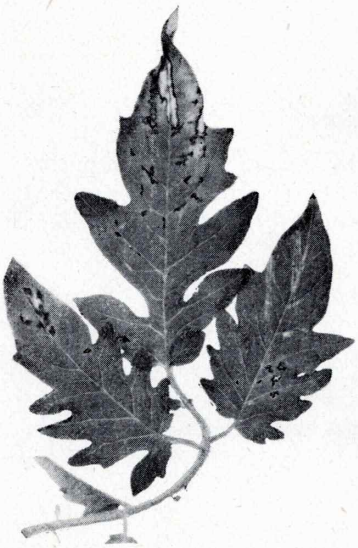


Fig. 21—Tomato-speck: spots on leaf. × ¾.
Photo by R. I. Hughes.

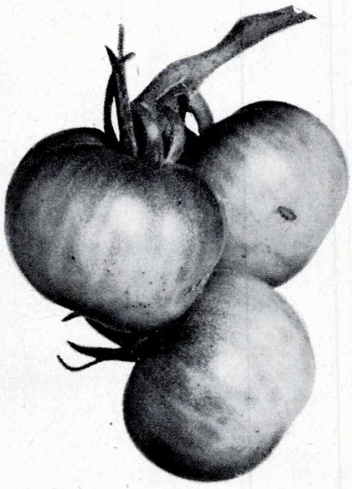


Fig. 22—Tomato-speck: pustules on green fruit. × 4/5.
Photo by R. I. Hughes.

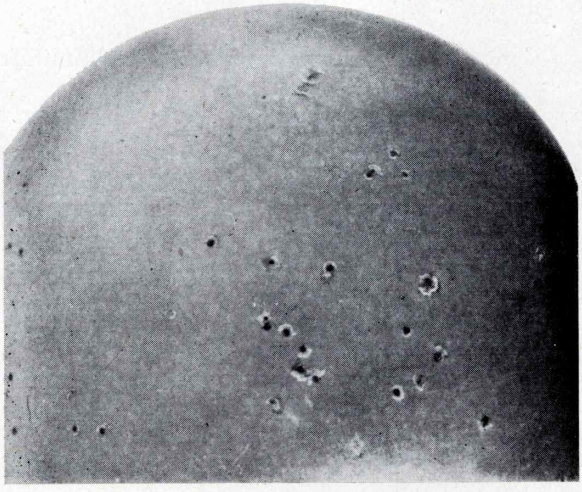


Fig. 23.
Tomato-speck: pustules with white margins on ripe fruit. × 3.
Photo by R. I. Hughes.

On fruits, specks occur as very small, round, slightly-raised pustules (Fig. 22). Each pustule is surrounded by a light halo which as the fruit matures forms a distinct white margin to the speck (Fig. 23). Lesions remain superficial and do not penetrate deeply into the flesh.

Natural stem infections have not been observed in New Zealand.

Young plants infected before or at time of planting out do not develop normally and are markedly stunted.

Factors Governing Spread of Disease

The evidence suggests that the disease is seed carried. Treatment of fruit pulp with hydrochloric acid (see page 78) will destroy any organisms on the seed, and dry seed can be successfully treated with acidulated mercuric chloride (see page 78).

The disease spreads rapidly in seed-boxes and because of the small size of spots, can be overlooked at time of planting out. It readily infects standard tomato varieties, and can be transmitted in a crop by cultivation and pruning.

The length of life of the causal organism in the soil is not known, but this will depend largely on the time taken by infected tomato refuse to decay.

Control

Control measures for tomato-speck are the same as those given for tomato-canker (see page 23).

CROWN-GALL

This disease, caused by *Bacterium tumefaciens* Smith and Townsend, is world-wide in distribution, and attacks an extremely wide range of host plants. In other countries, particularly in northern Europe, it is a serious disease, but in New Zealand has not been considered important.

Symptoms

Crown-gall is mainly a disease of roots or stem at or below ground-level, though it sometimes affects aerial parts. The usual symptom of infection is presence of more or less spherical galls or outgrowths on the tap root or main lateral roots (Fig. 24). They are generally firm and have a rough or creviced surface, and vary in diameter from one-quarter inch to half an inch. In New Zealand, the presence of galls does not usually seriously affect growth of the host plant.

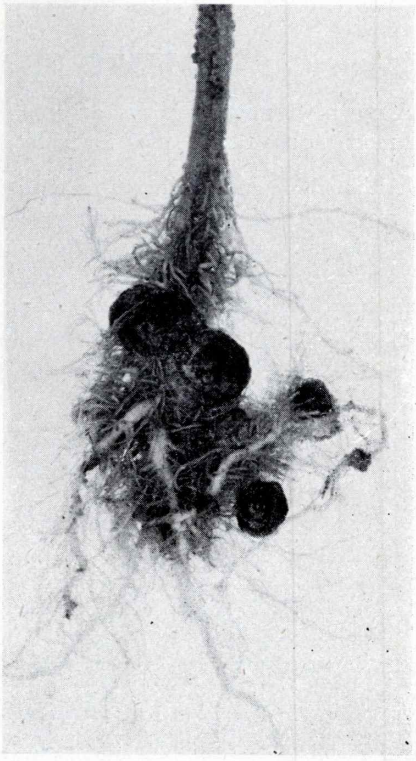


Fig. 24—Crown-gall: galls on tomato roots. × ½.
Photo by M. J. Dahlberg.

Factors Governing Spread of Disease

The disease organism is carried over from season to season in the soil or on growing crops, and is transmitted to new crops chiefly through root injuries. It is distributed from infected areas chiefly in galls or soil attached to infected plants. The organism prefers neutral or slightly acid conditions, but will not thrive in the acid soils common to New Zealand.

Control

1. Disinfect soil (see pages 92–99) or use soil which has not carried infected plants.

2. Do not apply heavy dressings of lime, particularly in areas where crown-gall is known to be present.

VIRUS DISEASES

VIRUSES are the simplest and smallest of known organisms, being indeed so small that they are invisible under the microscope. They differ from fungi and bacteria in that they cannot grow and multiply outside living host tissues. As the virus is present in the sap in all parts of an infected plant, recovery cannot be secured by the application of sprays or by any other treatment. Nor do plants recover naturally. Control measures are, therefore, limited to keeping a crop free from disease or preventing spread once it has appeared.

TOMATO SPOTTED-WILT

Known in some localities as bronze-top, tomato spotted-wilt is one of the most serious tomato diseases in New Zealand.

Although mainly a disease of outdoor crops, it occasionally occurs with serious results in glasshouses. It is more prevalent in some districts than others, losses being particularly heavy in Chritchurch, Hutt Valley and Auckland, where infections of up to 50 per cent. are not uncommon. During recent years the disease has become so prevalent in Christchurch areas that some growers have ceased growing outdoor tomatoes. Incidence is usually greater in the autumn, with the result that late crops sometimes become a total loss.

Fig. 25—Tomato spotted-wilt: plant on left showing bunched appearance of growing points which occurs during early stages of infection.

Photo by H. Drake.

Symptoms

The first noticeable symptom of the disease is a slightly bunched appearance of growing points, caused by cessation of growth, and downward curling and brittleness of stalks of developing leaves (Fig. 25). At this stage, older leaves are normal, but bronze or necrotic markings appear on young leaves, forming the most characteristic symptom of the disease. These markings, which vary in colour from light-bronze to almost black and are most numerous at the base of leaflets, occur as small isolated areas, as an irregular patchwork of dark tissues (Fig. 26), or as diffuse bronzing without definite margins. At first, markings are more noticeable on upper leaf surfaces. Later, as the

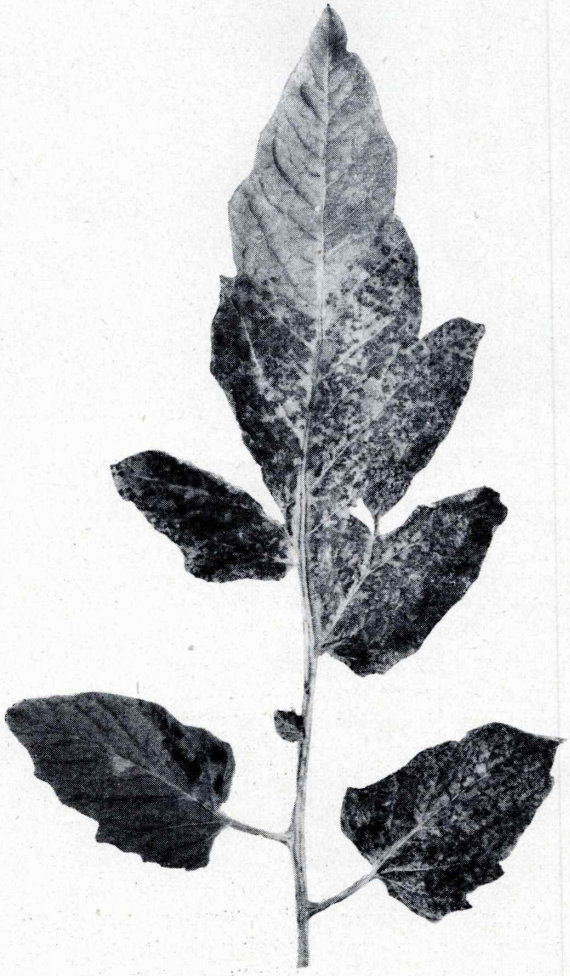


Fig. 26—Tomato spotted-wilt: dark markings on leaf. Natural size.
Photo by H. Drake.

disease develops, they also appear on the undersides. Affected areas increase in size until eventually some leaflets become brown and shrivelled. Dark patches or streaks may also appear on stems and leaf stalks. After a few weeks, diseased plants are markedly stunted in contrast to healthy ones (Fig. 27).

Fig. 27—Tomato spotted-wilt: stunting of plants in a portion of a crop severely infected with the disease.

Photo by H. Drake.

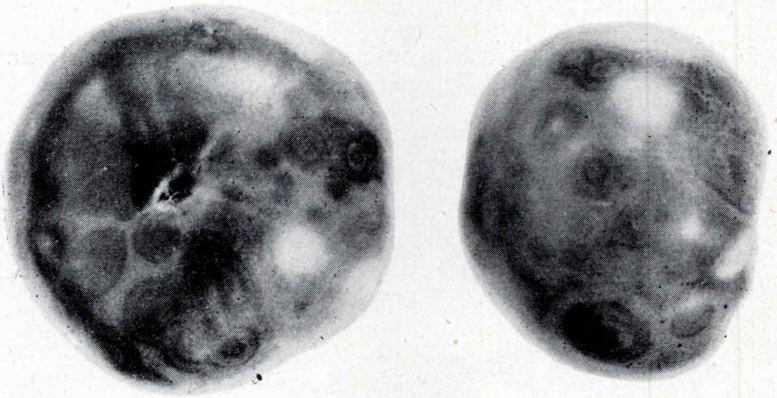
Occasionally, symptoms consist merely of a stunting of plants and a slight rolling of leaflets which become pale and tinted blue.

Infection occurs at all stages of growth. In young plants the disease often causes shrivelling of leaves and death of plants. Older plants remain alive in a stunted condition for several months. Sometimes such plants produce weak shoots which appear healthy until eventually bronzing reappears and growth again ceases. On plants which are nearly mature at time of infection, leaf symptoms are absent or only slight.

When infection takes place before the first truss is set, no fruit develops. Where the lower trusses have set, infection often causes bronzing and stunting of fruit. In such cases some fruit may develop and ripen though it will be small and of poor quality, frequently showing discoloured areas. These, which are light red, yellow or almost white, take the form of isolated circular areas, concentric circles or confluent patches covering a considerable portion of the fruit (Fig. 28). Such fruit, on account of its mottled appearance, is not

marketable. On plants which are nearly mature when infection takes place, fruit grows and ripens normally, but often shows the discoloured areas as described above.

The existence in New Zealand of several strains of tomato spotted-wilt virus accounts for the wide variations in symptoms.



Fog. 28—Tomato spotted-wilt: concentric markings on ripe friuts. Natural size.
Photo by H. Drake.

Host-range, Method of Spread and Overwintering

Spotted-wilt has a very wide host-range, being recorded in other countries as attacking a large number of species in many families. The following plants have been found susceptible in New Zealand: tomato, tobacco, lettuce, garden pea, Iceland poppy, aster, dahlia, anemone, flowering lupin, cineraria, zinnia, nasturtium, chrysanthemum, calendula, calla, primula, henbane, thorn apple and black nightshade. The disease is not seed carried, nor can the virus remain alive in dead plant debris. It is spread from plant to plant by thrips, transmission in New Zealand being confined to one species—the onion thrips.*

Spotted-wilt will overwinter on susceptible perennial or winter-growing plants, the main hosts being garden ornamentals such as dahlias, Iceland poppies, nasturtiums, calendulas, etc. During the spring and summer thrips migrate from such plants to tomatoes, carrying infection with them.

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* The adult of the onion thrips is a small, slender, brown to dark-brown insect approximately 1/20 inch long. The young forms are usually light-yellow and are wingless. It is similar to the thrips described on page 68.

Control

For districts where spotted-wilt is prevalent the following recommendations are made:—

1. Grow tomato crops as far as possible from flower gardens, lettuce crops, garden peas, or commercial plantings of Iceland poppies and anemones.

2. For two months following planting out, inspect crops at weekly intervals. Remove and destroy all diseased plants.

3. Keep crop and headlands free from weeds, paying particular attention to eradication of black nightshade and thorn apple.

4. In warmer districts, where nasturtiums are a common garden escape, eradicate this host wherever it grows in the vicinity of tomato crops.

5. In localities where tomato spotted-wilt occurs regularly in glasshouses, eradicate weeds from the area surrounding the houses and do not grow susceptible plants such as lettuce, Iceland poppies, dahlias, etc., in close proximity to them.

6. Once spotted-wilt has appeared in a glasshouse, its spread may be checked by fumigating with nicotine to kill the thrips (see page 87).

CUCUMBER-MOSAIC

Cucumber-mosaic was first recorded on tomatoes in New Zealand under the name of "tomato narrow-leaf." Outdoor tomatoes are affected more than those grown in the glasshouse, where the mosaic is found only occasionally. Although it is present in all districts, serious losses are confined to particular localities. In Poverty Bay and North Canterbury infections of over 50 per cent. have been recorded, while both Hawke's Bay and Manawatu areas have suffered heavily.

Reduction of crop yields by cucumber-mosaic varies with the age of plants when infection takes place, and with conditions of growth. When plants become infected shortly after they are set out in the field, yield is reduced by approximately 80 per cent.

Symptoms

Although plants may become infected at any stage of growth, symptoms frequently appear between setting of the first and second trusses, the first indication being a distinct narrowness of young leaves. With further growth this becomes more pronounced, distortion and curling of leaves being apparent in severe cases (Figs. 29 and 31). Occasionally the leaf surface is so reduced

Fig. 29—Cucumber-mosaic: narrowing and distortion of leaf. × 2/3.
Photo by H. Drake.

Fig. 30—Cucumber-mosaic: extreme narrowing of leaf. × 2/3.
Photo by H. Drake.

that narrowness is extreme (Fig. 30). Leaves fully developed at time of infection remain unchanged. Height of plants is not greatly affected (Fig. 31), but narrowing of leaves results in a reduction of the total leaf area, while fruits are smaller than normal, inclined to be flattened and of light weight. The effects are sometimes so severe that fruit fails to set on the upper trusses.

Host-range, Method of Spread and Overwintering

Cucumber-mosaic attacks a large number of plants in addition to tomatoes. In other countries over eighty species, including many flower plants, vegetables and weeds, have been recorded as susceptible. In New Zealand the disease is known to occur on tomato, cucumber, marrow, pumpkin, rock melon, tree tomato, polyanthus, viola, pansy and violet, but it is undoubtedly common to many other plants.

Natural spread of the disease is by aphids, commonly known as green-aphis (see page 68), three species of which have been found to transmit it in New Zealand. As their feeding extends over a wide range of plants, these

Fig. 31—Cucumber-mosaic: comparison of healthy and infected plants.
Photo by H. Drake.

insects may carry the disease to tomato crops from infected plants other than tomatoes.

Cucumber-mosaic may also be spread by workmen whose fingers become contaminated when they handle infected plants during tying and removal of laterals.

As the virus is not seed-borne and cannot persist other than in living tissues, the carry-over from one crop to the next must be through growing plants. Normally the disease overwinters on infected flower plants, vegetable crops or weeds.

Control

In districts where cucumber-mosaic is prevalent the following precautions are recommended:—

1. Do not grow cucumbers, marrows, pumpkins or rock melons in the vicinity of tomato crops.
2. Grow tomato crops as far removed as possible from flower gardens (many flowers are susceptible to cucumber-mosaic).
3. Keep down weed growth within the crop, as many weeds also are capable of carrying infection.
4. Inspect tomato crops at regular intervals of about one week. Remove and destroy all infected plants.
5. Do not touch healthy plants after diseased ones have been handled.
6. Wash hands thoroughly with soap and water after handling infected plants.

Where cucumber-mosaic occurs in glasshouses, spread of infection may be checked by fumigation with nicotine to destroy aphids which carry the virus (see page 87).

TOBACCO-MOSAIC

Tobacco-mosaic, sometimes known as tomato-mosaic, is the commonest virus disease of glasshouse tomatoes. It is prevalent throughout all districts, recent surveys of glasshouse crops having shown that average infection approximates 16 per cent. Infections of 100 per cent. are not unusual and 50 per cent. or more in some crops is common in all districts. Although reduction in yield is usually less than 25 per cent., the high incidence of tobacco-mosaic makes it a serious glasshouse disease. It also occurs in the field, where its detection is often difficult.

Symptoms

In the glasshouse, foliage of infected plants shows a light and dark-green mottling (Fig. 32), this condition being seen most readily when leaves are shaded or held to the light. Leaves are small and sometimes show a puckered or uneven surface. At times during periods of low-light intensity such as occur during winter months, leaves become narrow with pointed lobes (Fig. 33), giving plants a fern-like appearance. Plants are slightly stunted, the amount of foliage reduced and yield of fruit lessened. Stems may be less sturdy than those of healthy plants, but retain their normal green colour. Fruits, although sometimes small, are not otherwise altered in appearance.

Symptoms in the field are less pronounced, mottling usually being discernable in young leaves only. Although plants infected early in the season may be sightly stunted and the amount of foliage reduced, later infections often appear to have little effect on growth of plants.

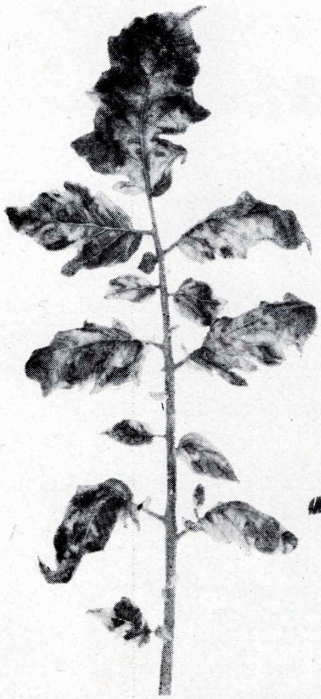


Fig. 32—Tobacco-mosaic: mottling of leaf. × 2/3.
Photo by L. H. Wright.

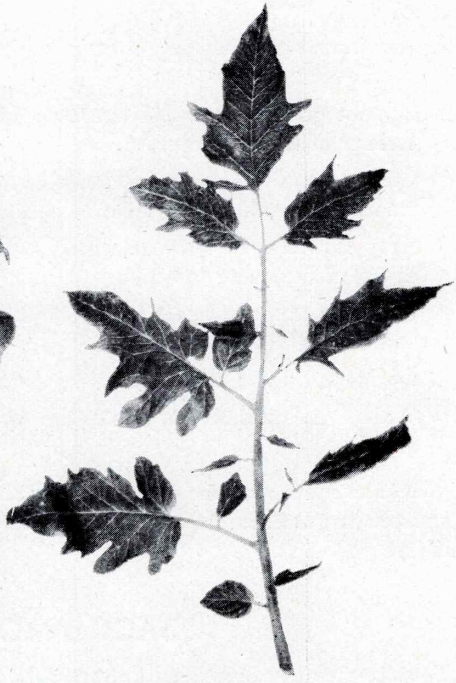


Fig. 33—Tobacco-mosaic: mottling and distortion of leaf brought about by the disease under conditions of low light intensity. × 2/5.
Photo by L. H. Wright.

Host-range, Method of Spread and Overwintering

The host-range of tobacco-mosaic is restricted to a group of plants closely related to tomato. In New Zealand the disease has been found on tomato, tobacco, cape gooseberry, pepper and black nightshade.

It is not transmitted by insects, but is readily spread by contact between diseased and healthy plants or by contaminated implements and hands of workmen. Of these, the last is the most serious, since the handling of one infected plant will eventually lead to contamination of the whole house. Because the virus remains alive for many years in dry plant tissues, being present in practically all manufactured tobacco, introduction to a crop may take place through fingers of smokers. In roots and other plant remains left in the soil it persists from one season to the next. This occurs more often in the glasshouse, where there is no weathering to leach out the virus. When plants are set directly into soil from which infected plants have been removed, a high percentage of them contract the disease.

Although not carried within tomato seed, the virus is present in the gelatinous coat, seed transmission taking place if the seed is not properly cleaned. Extraction by acid treatment (see page 78), however, removes these seed coats and eliminates infection.

Control

The number of sources from which tobacco-mosaic may be introduced increases the difficulty of keeping crops free from infection. Nevertheless, provided adequate precautions are taken, this troublesome disease can be effectively controlled.

Control recommendations are:—

1. Save seed from disease-free plants only, and as an added precaution clean it by acid treatment (see page 78).

2. Use steam disinfected soil in seed and seedling-boxes (see page 92).

3. Steam disinfect soil (see page 92) in glasshouses where tobacco-mosaic has been present in the previous crop.

4. In cases where steam disinfection of soil is impossible, the plants should be removed as soon as harvesting is completed and a cover crop such as maize, which will tolerate heavy watering, sown down immediately. Water heavily while cover crop is growing and again when it is dug in. In this way the virus is leached from the soil.

5. Isolate both seedling areas and tomato gardens as much as possible from tobacco or cape gooseberry crops and eradicate black nightshade plants.

6. Inspect seedlings in boxes before setting out plants. Do not set out plants from boxes in which tobacco-mosaic infection has been detected.

7. Workers should refrain from smoking while handling plants. If this condition cannot be observed, they should wash their hands thoroughly with soap and water after touching tobacco.

8. Avoid contamination from other hosts—tobacco, cape gooseberry and black nightshade.

9. Remove and destroy diseased tomato plants as soon as they are noticed in the crop.

10. Remove soil surrounding infected plants when replacing them and fill in with clean soil before replanting.

11. Avoid handling infected plants when working with healthy ones.

12. Thoroughly wash hands with soap and water to remove contamination whenever infected plants have been handled.

13. At the end of the season remove all plants together with as many roots as possible, fallen leaves, etc., and destroy by burning.

Fig. 34—Tomato-streak: dark streaks on stem and leaf stalks. Natural size.
Photo by H. Drake.

TOMATO-STREAK

Coming first into prominence in the Hutt Valley, where it caused serious losses during the 1922–23 season, tomato-streak, also known as stripe or black-stripe, occurs throughout the country. Most common in glasshouses, it sometimes reaches serious proportions in the field. Recent surveys of glasshouse crops throughout New Zealand have shown average infection to be between two and three per cent., while twenty to fifty per cent. is fairly common in some houses. Infections as high as seventy per cent. have been observed in Auckland glasshouses.

Field incidence was particularly high in the Hutt Valley during the 1940–45 period, many crops showing twenty-five to one hundred per cent. diseased plants. A high percentage of infection is serious, as diseased plants yield little or no marketable fruit.

Symptoms

Black streaks on stems and leaf stalks are the most characteristic symptom of the disease (Fig. 34). In advanced stages the streaks become sunken (Fig. 35). Development of dark areas of dead tissue often causes leaves to become brown and shrivelled, while a slight mosaic mottling sometimes

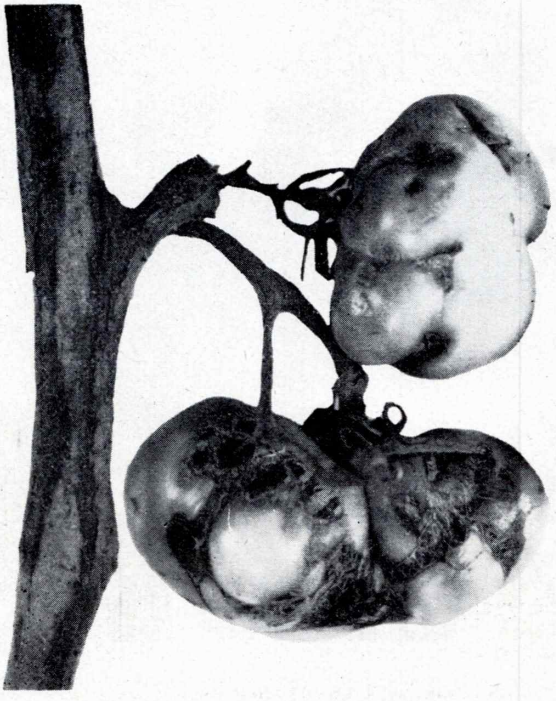


Fig. 35—Tomato-streak: portion of an infected plant showing dark streaks on stem and dark scabby areas on green fruit. × 4/5.

Photo by H. Drake.

appears, especially on young leaves. Usually symptoms do not appear until plants have set fruit on the bottom three or four trusses, but occasionally they have been observed on young plants shortly after setting out in the glasshouse. Plants infected when small are stunted, while those developing symptoms at a later stage lose much of their foliage and present an unthrifty appearance. Flowers frequently fail to set or young fruits to develop.

The occurrence on young fruits of dark areas which remain sunken as the fruit grows produces a pock-marked

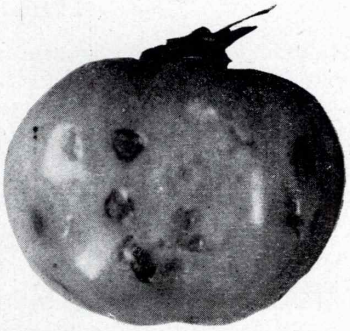


Fig. 36—Tomato-streak: isolated depressed areas on green fruit. Natural size.
Photo by H. Drake.

Fig. 37—Tomato-streak: ripe fruit showing uneven surface, produced by sunken dark markings. × 4/5.
Photo by H. Drake.

effect (Fig. 36). Later the affected areas sometimes develop cracks, giving the fruit a scabby appearance (Fig. 35).

Symptoms also develop on more mature fruits, usually appearing as narrow bands of darkened tissues sometimes arranged in arcs or circles. These, too, remain sunken as the fruit grows, but do not crack. Such fruits have smooth, raised areas which give them an uneven surface (Fig. 37).

Tomato-streak may also produce symptoms identical with those of tobacco-mosaic. Conditions governing the development of one type of symptom or the other are not known.

Tomato-streak and Tobacco-mosaic are Strains of the Same Virus

Tomato-streak is a strain of the tobacco-mosaic virus and, therefore, has the same host-range, methods of transmission and other characteristics. It differs from tobacco-mosaic only in its symptoms on tomato and tobacco. As tobacco is not susceptible under field conditions, however, manufactured tobaccos do not carry infection.

Control

Control measures are the same as for tobacco-mosaic (see page 35).

SEVERE TOMATO-STREAK

Severe tomato-streak, also known as severe tomato-mosaic, is caused by a combination of tobacco-mosaic (see page 35) and potato X virus. Although

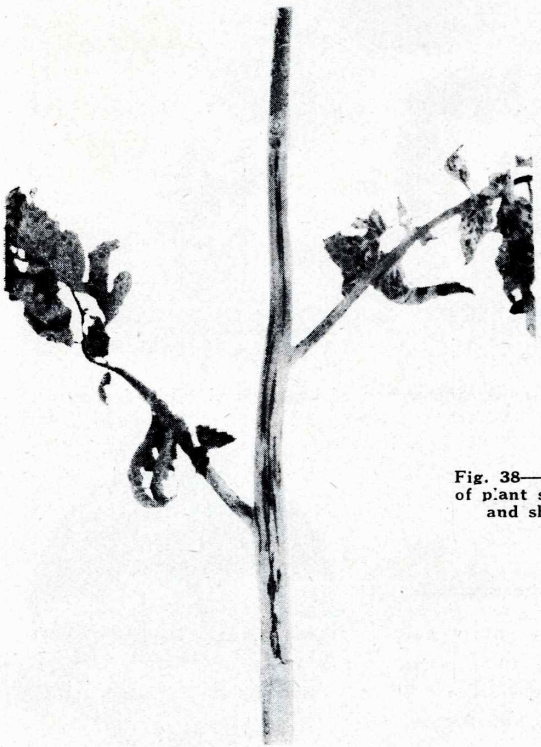


Fig. 38—Severe tomato-streak: portion of plant showing dark streaks on stem and shrivelling of foliage. × ½.
Photo by W. E. Barnard.

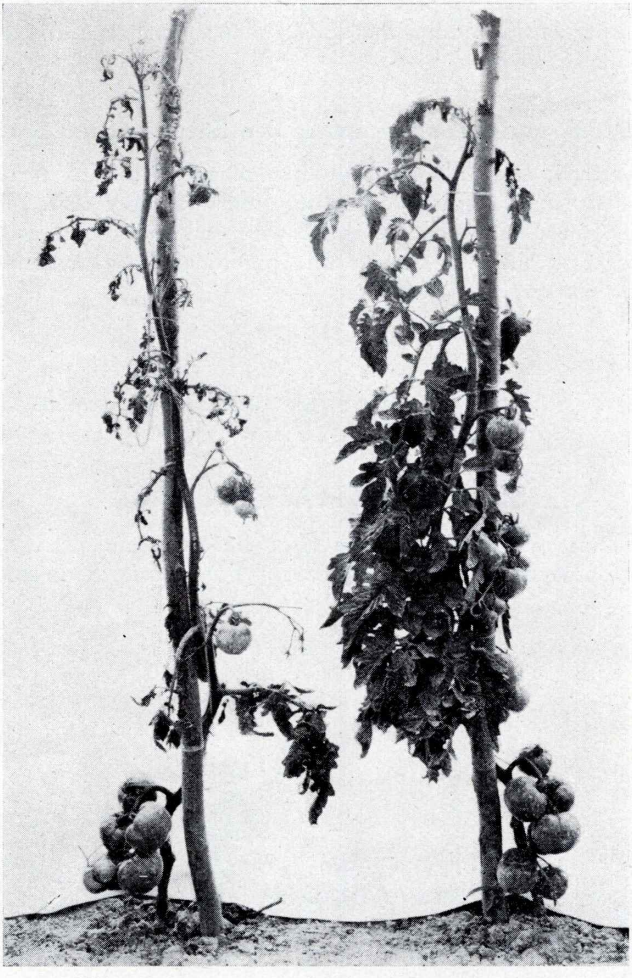


Fig. 39—Severe tomato-streak: comparison of healthy and infected plants.
Photo by H. Drake.

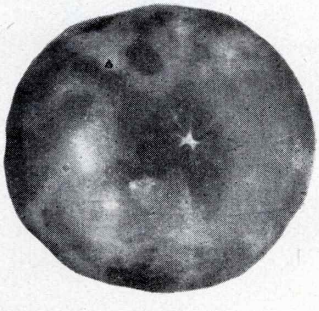


Fig. 40—Severe tomato-streak: mottling of ripe fruit. × 4/5.
Photo by H. Drake.

of sporadic occurrence only, once established it spreads rapidly. In some seasons it has caused considerable damage to glasshouse tomatoes at Nelson and to dwarf tomatoes in the field at Auckland. It also occurs occasionally in other districts.

Symptoms

Leaves of infected plants are small, mottled, curled, and show light or dark-brown dead areas (Fig. 38). The last occur as spots between the veins which sometimes extend until the whole leaf blade becomes brown and shrivelled. Numerous dark streaks occur on stems and leaf stalks (Fig. 38), the former becoming brittle and showing internal discolouration. Plants infected when young are stunted, while those infected later fail to set fruit on upper trusses (Fig. 39). Many leaves die and fall. Fruit is small and when ripe shows pronounced mottling (Fig. 40). On dwarf tomatoes, in addition to the above symptoms, leaves tend to roll.

Control

Like tobacco-mosaic, severe tomato-streak is very infectious, spread occurring through handling of plants during cultural operations. Potato X virus does not itself cause a disease of tomatoes and has not been observed occurring alone. Control, therefore, is best effected by applying measures recommended for control of tobacco-mosaic (see page 35).

PHYSIOLOGICAL DISEASES

UNDER this heading are grouped all those abnormal conditions for which no causal organism or virus can be found. Such diseases are caused by some unfavourable factor in the general conditions of growth. Thus a disturbed water supply, adverse weather conditions, or chemical injury can all produce disease symptoms. Tomatoes are subject to several diseases of this type, and details of those known to occur in New Zealand are set out below.

BLOSSOM-END ROT

This physiological disease may occur in both field and glasshouse crops in any tomato-growing district. Some varieties are less subject to blossom-end rot than others, but all are affected to some degree. Under drought conditions it can cause heavy loss, but under normal conditions wastage is slight.

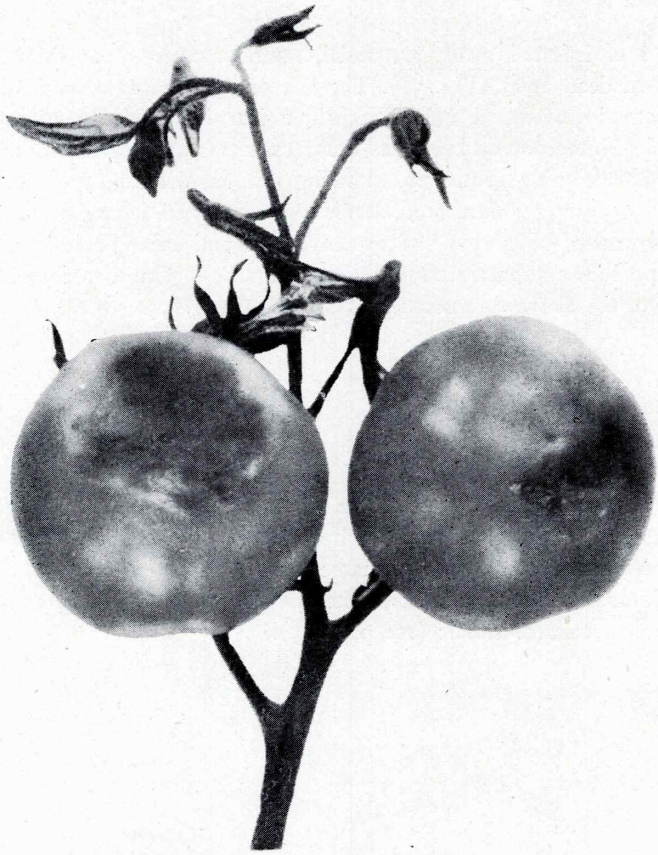


Fig. 41—Blossom-end rot: early stages on fruit. Natural size.
Photo by H. Drake.

Symptoms

Fruits are most commonly affected when about half-grown, but they may be injured at practically any stage. The trouble first appears as a water-soaked spot near the blossom end (Fig. 41), which darkens and increases in size until it may cover from a third to half the fruit. Shape is not affected initially, but

the healthy part continues to grow while the dead tissues shrink. The spot becomes depressed with a dark-brown, tough, leathery surface (Fig. 42). Bacteria and fungi often attack these dead areas, producing a soft rot that may involve the whole fruit.

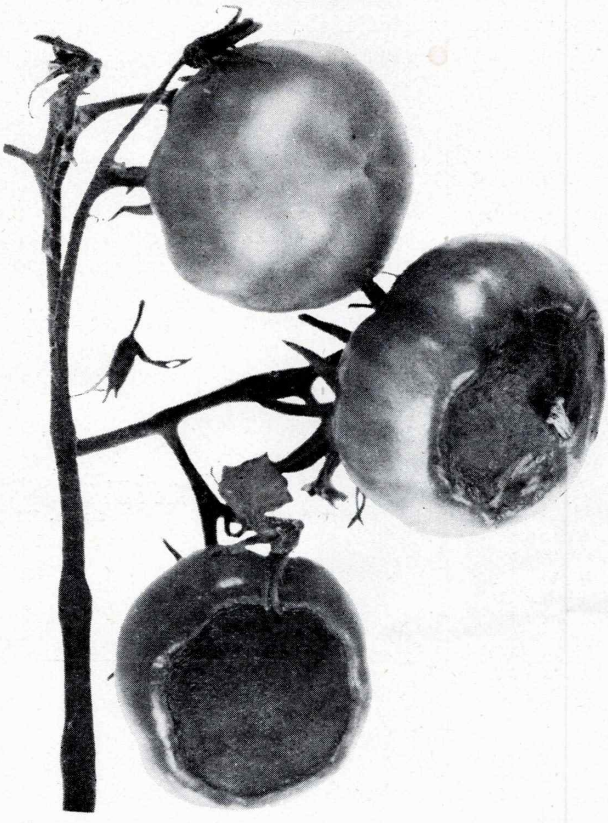


Fig. 42—Blossom-end rot: advanced stage, showing depressed leathery areas at blossom end. Natural size.

Photo by H. Drake.

Cause

Blossom-end rot is caused by an unfavourable water supply. Both continued excessive water or a sudden change from abundant water to drought will induce the disease, the later being the most usual cause in New Zealand. Hot winds and periods of high temperature during a drought tend to aggravate the trouble. Excessive use of nitrogenous manures containing ammonia, such as ammonium sulphate or dried blood, may increase the amount of rot when other conditions are favourable to its development, and a marked shortage of lime appears to have the same effect.

Prevention

An adequate and regular water supply, particularly after fruit has begun to develop, will largely prevent appearance of the disease, and good cultivation should be maintained to conserve this water. The use of nitrate of soda in preference to other nitrogenous manures, combined with ample dressings of phosphate, and moderate amounts of lime will help to reduce loss in areas that are particularly susceptible. Light sandy soils, and in particular sandy ridges, should not be planted with tomatoes, as they are subject to repeated droughts.

BLOTCHY-RIPENING

Blotchy-ripening, sometimes known as cloud or cloudy-fruit, is primarily a glasshouse disorder, but sometimes occurs in outdoor crops. It has been found in all the major tomato-growing districts of New Zealand, and in some seasons it causes serious reduction in quality of the earliest fruit.

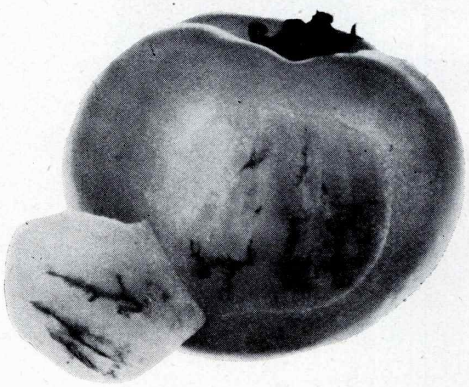


Fig. 43 — Blotchy-ripening: sectioned fruit showing dark vascular tissue. × ¾.
Photo by L. H. Wright.

Symptoms

First signs of the disease appear when the lowest truss is approaching maturity. At this stage hard, dark-green, dingy-looking patches develop on the fruit. Immediately below the surface of these patches there are strands of dark-brown or black tissue, these being diseased vascular bundles (Fig. 43). As the fruit ripens affected areas gradually turn yellow, presenting a marked contrast to the bright red of healthy tissue (Fig. 44). Such fruit is edible, but its quality is lowered by the patches with their network of dark vascular bundles. Blotchy-ripening occurs most frequently in heavy crops, and is normally only found in the first three trusses.

Cause

The cause of this disease is not yet fully understood, but is thought to be a form of malnutrition. Light intensity, water supply, and the availability of plant food in the soil all affect the development of blotchy-ripening, but the exact parts played by the various factors have not yet been determined.

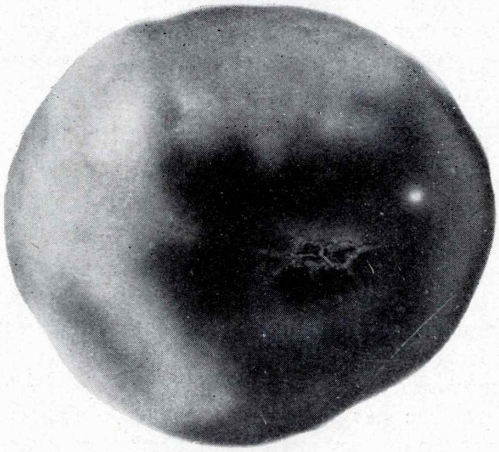


Fig. 44—Blotchy-ripening: ripe fruit showing large light-coloured blotch. × 4/5.
Photo by W. E. Barnard.

Prevention

British workers have obtained control of blotchy-ripening by heavy application of potash fertilisers. Repeated attempts to obtain control by these means have been made in New Zealand, but without success. All that is known at present is that the disease can be kept in check by reducing watering to a minimum during the time that the first three trusses are approaching maturity.

HARD-CORE

Throughout New Zealand outdoor tomatoes are liable to develop hard-core, or, as it is sometimes known, green-back. It is rarely found in glasshouse crops. This trouble can cause serious losses to individual crops, but is rarely severe over large areas.

Symptoms

Hard-core first shows itself as a hardening of the tissues round the stem end of the fruit. While the remainder of the fruit is colouring, the stem end

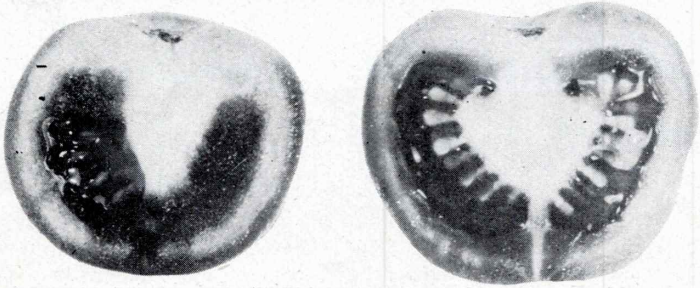


Fig. 45—Hard-core: fruit at left showing hard tissues extending to calyx end, less severe case on right. × ¾.
Photo by M. J. Dahlberg.

remains hard and green, finally changing to yellow or orange when the fruit is fully ripe. Even when yellow, affected tissue is still hard and unpalatable. In extreme cases, hard tissues extend almost to the calyx end, but may have a thin layer of normal red tissue covering them (Fig. 45). Such fruits are of no value. There appear to be slight differences in varietal susceptibility, but no variety is immune.

Cause

In England the disease is attributed to high temperatures causing injury to the upper part of the fruit, and it is claimed that plants deficient in potash are particularly susceptible. Attempts to prevent hard-core under local conditions by increasing the proportion of potash in normal fertiliser dressings have not been successful, but soil sterilization with steam or chloropicrin has reduced the percentage loss under experimental conditions. There is also some evidence that the disease may be reduced by the use of organic manures together with a combined nitrogen, phosphate, and potash fertiliser.

Prevention

It is not yet known whether the disease is primarily nutritional, climatic, or a combination of both, and for the present no reliable means of prevention can be recommended.

HORMONE WEEDKILLER INJURY

The introduction of hormone weedkillers has brought a new danger to tomato-growing. Even traces of weedkillers that contain a substance known as 2, 4–D cause severe foliage distortion and serious loss of crop.

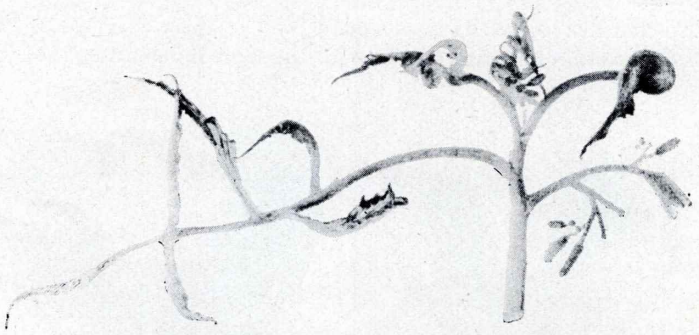


Fig. 46—Hormone weedkiller-injury: growing point showing narrowing and distortion of leaves. × ½.

Photo by R. I. Hughes.

Symptoms

First signs of damage are spiral twisting of the growing points and leaf stems, and drooping of leaflets. A few days later leaves may recover, but a permanent twist remains in the main stem. About a fortnight from the time contamination occurs, new leaves show the extreme narrowing and curling that is characteristic of this hormone injury (Fig. 46). Plants continue to grow, but, except in rare cases, all later leaves are of this spindly, fern-like type, and any fruit formed is elongated, beaked, and hollow. Affected plants are of no value.

These symptoms are very similar to those produced by cucumber-mosaic (see page 32). Cucumber-mosaic usually appears first on a few scattered plants and spreads from these, while in a crop damaged by hormone weed-killer, leaf distortion shows on many plants at the same time. This difference gives a reasonably clear indication of the cause of the damage. Diagnosis is also helped by the fact that on 2, 4–D injured plants, leaf veins show up prominently and run almost parallel to the mid-rib (Fig. 47). Leaves infected with cucumber-mosaic do not show this peculiarity.

Where drift from a spray of weedkilling strength reaches tomatoes they collapse and die within a few days.

Cause

Dangerous hormone residues are liable to reach tomatoes in three ways—as residues in spray pumps, as spray drift, or as vapour from treated weeds within 30 to 40 feet of the crop. In practice, the first is the most common cause of trouble. At present there is no known way of removing all harmful residues from a pump that has once been used for spraying with 2, 4–D. Neither rinsing with kerosene nor thorough washing with hot or cold water will remove this hormone material from pumps, and washing with 10 per cent. caustic has also failed.

Prevention

Nothing can be done to cure affected plants. Injury can best be prevented by keeping this form of weedkiller as far away as possible from tomato plants. If it must be used, then there should be two pumps, one for weedkiller and a second for all normal spraying.

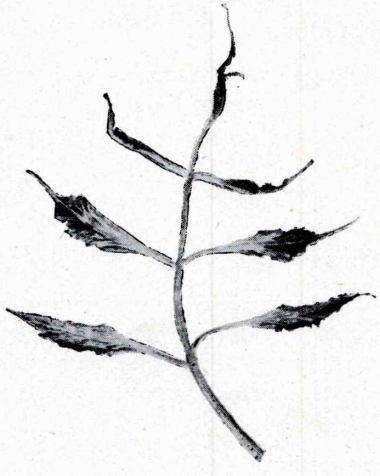


Fig. 47 — Hormone weedkiller-injury: leaves narrow with prominent, almost parallel veins. × ½.
Photo by R. I. Hughes.

GROWTH-CRACKS

Cracking is a common cause of poor quality in tomato fruits, and is liable to occur in any crop.

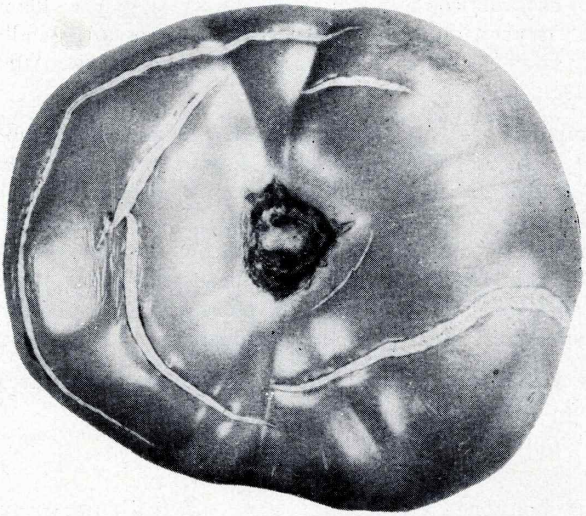


Fig. 48—Growth-cracks: at stem end of fruit. Natural size.
Photo by H. Drake.

Symptoms

Cracks usually occur at the stem end, where they tend to radiate out from the stem, or form roughly concentric rings round the shoulders of the fruit (Fig. 48). If they develop slowly the exposed tissue dries and hardens, but is liable to break during handling. Where cracks form rapidly they may extend deep into the flesh, providing ready entry for organisms causing rots.

Cause

Some varieties are naturally prone to cracking, but it can occur in any variety. The trouble usually appears during warm, wet periods when growth is extremely rapid, but it may also develop when a period of high rainfall coincides with the ripening of fruit that has developed under dry conditions.

Prevention

Cracking can be reduced in irrigated crops by using a minimum amount of water from the time the fruit starts to colour. Where a variety is consistently subject to cracking it should be changed for one more suited to that locality. No other methods of checking this trouble are known.

SUNSCALD

Whenever green tomatoes are exposed to direct sunlight, sunscald is liable to occur. In normal healthy crops losses are small, but in years of intense sunlight, or in crops affected by diseases damaging the leaves, losses may become significant.

Symptoms

Sunscald usually appears first as a light-coloured patch on the side of green fruit open to the sun. Where damage is slight, this area turns yellow as the fruit ripens, but where injury is more severe the skin turns almost white, and the damaged spot resembles a blister. Later this shrinks and forms a flattened greyish-white spot with a dry, papery surface. Under some conditions fungi and bacteria establish themselves on these injuries, producing growths of various colours and some degree of fruit-rotting.

Cause

This disorder is produced by the effect of direct sunlight on fruit tissue that has not been gradually hardened. Any factor that causes a premature shedding of the leaves increases the risk of sunscald, but injury will also occur where healthy plants are disturbed in such a way that their fruit is exposed.

Prevention

Control of those diseases that cause defoliation will largely prevent sunscald, as normal healthy foliage is sufficient protection, except in extremely hot, dry seasons. Where fruit has become exposed, any form of shading will materially reduce injury, and a thin layer of hay or straw over the bunches will serve this purpose.

CATFACE

Comparatively small numbers of extremely distorted fruits are liable to occur in any tomato crop. This trouble, known as catface, may cause appreciable loss in unfavourable seasons, but is generally of only minor significance.

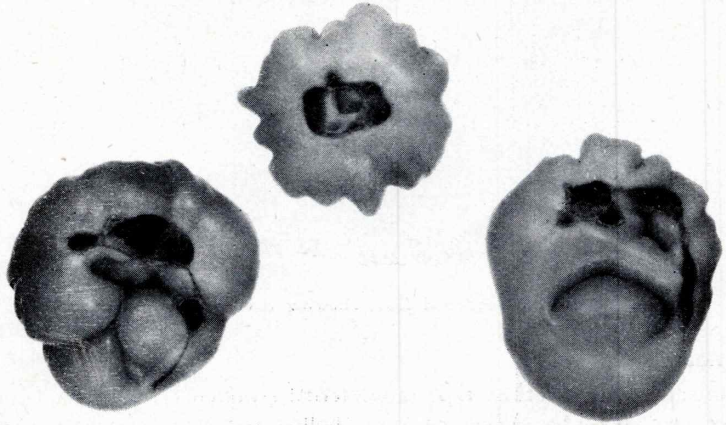


Fig. 49—Catface: showing distorted blossom end of dwarf tomato fruits. × ¾.
Photo by L. H. Wright.

Symptoms

Affected fruits are puckered and distorted at the blossom-end, with bulbous projections, and depressions that run deep into the fruit (Fig. 49). Between the swellings, areas of rough scar tissue often occur. Fruit of this type ripens unevenly and is of no value commercially.

Cause

Catface is caused by any factor that disturbs normal development and fertilization of the flower. The exact way in which flower parts are injured is not known, but cold wet weather during setting appears to play some part. Varietal reaction also appears to be involved, as there is some evidence of differing varietal susceptibility.

Prevention

There is no known way of controlling catface. Where the trouble is persistent in any particular variety, an improvement can usually be obtained by changing to some other tomato more suited to the particular locality. The most suitable variety can only be determined by trial and error.

POCKETS

Pockets or hollow-fruit has been found in some glasshouse crops, but is a comparatively rare disease in New Zealand. The market value of affected fruits is considerably reduced by their flabby condition and light weight.

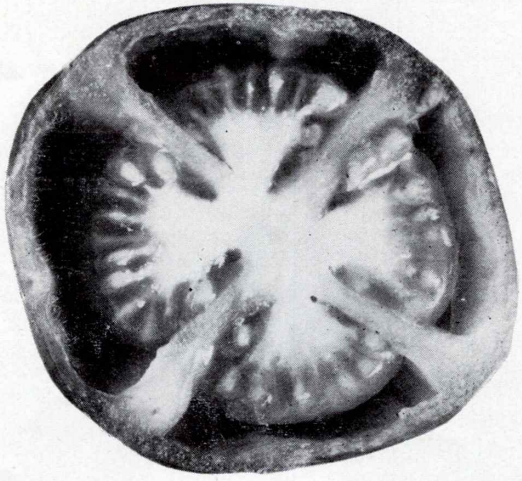


Fig. 50—Pockets: sectioned fruit showing cavities. Natural size.
Photo by R. I. Hughes.

Symptoms

Fruit affected by pockets show no external symptoms, but when handled they feel soft and flabby. When cut open, hollow pockets are found separating the seed-bearing pulp from the outer layer of flesh (Fig. 50). Such fruits have

normal flavour, and do not rot any more readily than firm tomatoes, but they squash badly when packed.

Where tomatoes are affected by hormones of the 2, 4–D group, an exaggerated form of pockets may develop. Induced injury of this type can be recognised by the fact that such fruit is seedless.

Cause

American work indicates that several factors are involved in the formation of pockets. Excessively high or very low temperatures, and too much water or drought all appear to be contributing factors, while fertiliser applications also play some part.

Prevention

With so many cultural conditions affecting the development of pockets, it is apparent that there can be no simple remedy. Where temperatures and soil moisture can be kept at normal levels little trouble occurs. There is also some evidence that liberal use of phosphate together with sparing use of nitrogen will reduce the incidence of pockets.

FRUIT-SPLITTING

A new form of injury has been found during the past two seasons on fruit of the varieties Potentate and Carter's Sunrise. The trouble is not serious and only a small percentage of fruits from the first three trusses have been affected in any one crop.

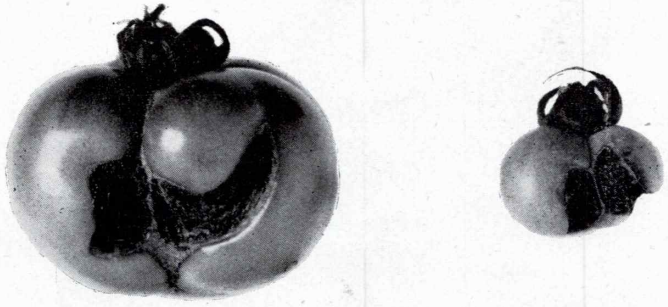


Fig. 51—Fruit-splitting: young fruits with splits on side, exposing seeds. Natural sze.
Photo by R. I. Hughes.

Symptoms

Early in the development of young fruit, splits appear on the side or blossom end. As growth continues, these open into wide, shallow depressions that expose some of the partly-grown seeds (Fig. 51). Tissues lining the injuries dry and harden to a deep-brown, usually being quite firm. Secondary organisms may gain entry through the spilts and cause rotting.

Cause

No disease-producing organisms have been found in association with these splits, and the cause is at present unknown.

Prevention

No method of treatment is known. As the disease has only been observed on a small percentage of fruits from two varieties, and is not infectious, it is unlikely to be of economic significance.

LEAF-TWIST

This disease has appeared on glasshouse-grown tomatoes during recent years, being first observed in 1944. It occurs mainly on the Potentate variety, incidence sometimes reaching ten to fifteen per cent. The brittleness of leaf stalks during early stages of the disease may result in loss of a considerable number of leaves, with consequent reduction in yield of fruit.

Symptoms

Symptoms first appear on vigorously growing plants, when they are one to two feet tall, as a pronounced downward twisting of leaf stalks near the

Fig. 52—Leaf-twist: showing downward twisting of leaf-stalk and dark streak (indicated by arrow) on underside.
Photo by R. I. Hughes.

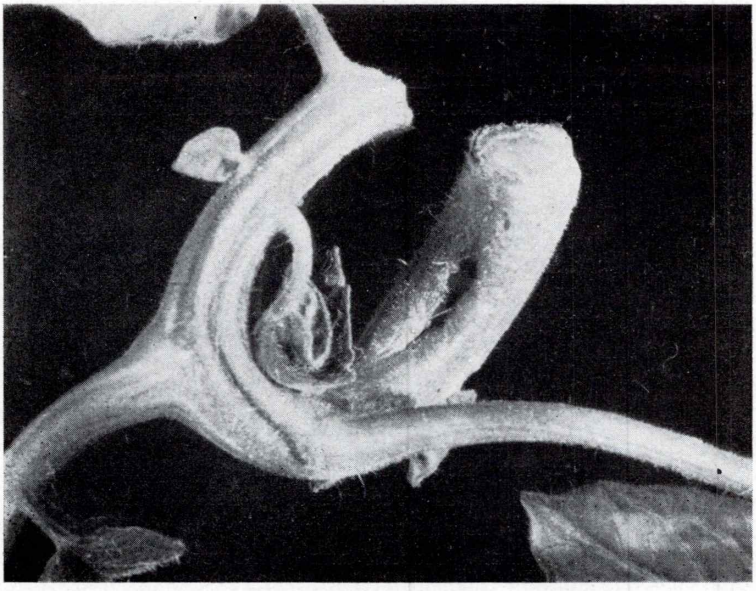


Fig. 53—Leaf-twist: later stage showing extreme twisting and sunken area near base of leaf stalk. X 1¼.

Photo by R. I. Hughes.

top of the plant (Fig. 52). Examination reveals the presence of dark, scabby streaks on the underside near the base of leaf stalks (Fig. 52). At this stage the stalks are extremely brittle and leaves are readily broken off when plants are handled during lateralling and training. As the plants grow, leaves remain twisted and the dark streaks become sunken (Fig. 53). Affected leaves gradually lose their brittleness, and the danger of breaking them off diminishes. The disease ceases to develop as plants mature.

Prevention

Since leaf-twist is not caused by a disease organism, but is brought about by some inherent weakness, it does not spread from plant to plant. Removal of affected tomatoes is therefore unnecessary. Although there is no known means of preventing it, the disease causes little or no damage provided the leaves are not broken off. Special care should therefore be taken when handling plants during the period immediately following its appearance.

INSECT PESTS

Insect pests of tomato can be divided into three groups according to their manner of feeding. The first include all those that chew, the second those with sucking mouthparts, and the third those that rasp the plant surface and suck up exuded sap. Feeding habits largely determine the type of

insecticide used to control any particular insect, stomach poisons being used for chewing insects and contact poisons for other forms.

In the following pages, insects are grouped according to their methods of feeding. Pests other than insects then follow in the " Miscellaneous " group.

CHEWING INSECTS

CATERPILLARS

These are of two types (a) looper-caterpillar (*Plusia chalcites* Esp. and (b) tomato-caterpillar (*Heliothis armiger* Hl.).

Importance, Type of Injury and Distribution

Caterpillars are among the most serious and widespread pests of the tomato. Their presence is readily recognised by holes eaten in leaves and fruits (Figs. 54 and 55). Large areas of foliage may be devoured, thus reducing the vigour of plants. Greatest damage, however, is caused to fruits, those attacked being unmarketable. They occur throughout the Dominion.

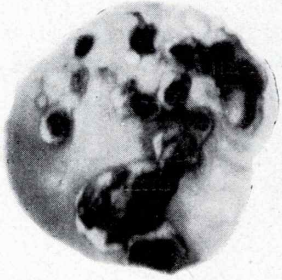


Fig. 54—Caterpillars: damage caused to tomato fruit. Natural size.
Photo by H. Drake.

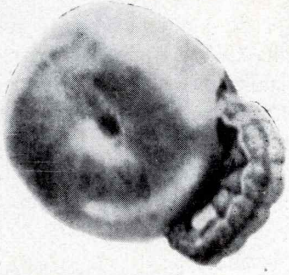
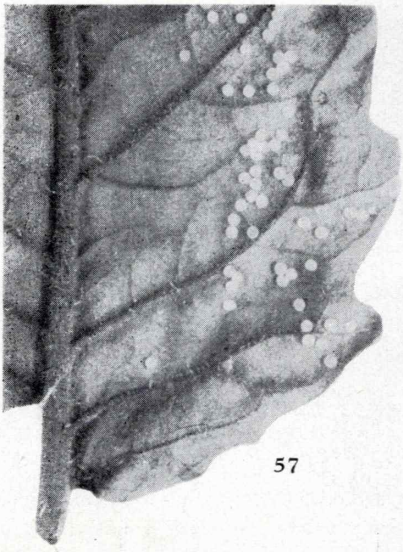


Fig. 55—Tomato-caterpillar: caterpillar eating into fruit. Natural size.
After Miller.

Appearance, Life-history and Habits

Looper-caterpillar

The caterpillar, which is green, is about $1\frac{1}{4}$–$1\frac{1}{2}$ inches long when fully grown. It can usually be distinguished by its habit of progressing with a looping motion; when disturbed, it will frequently remain attached to the plant by the hind end of the body and wave the remainder about in the air in wide sweeps. The adult is a dark-brown moth with iridescent fore-wings, each of which bears two golden spots very close together near the centre



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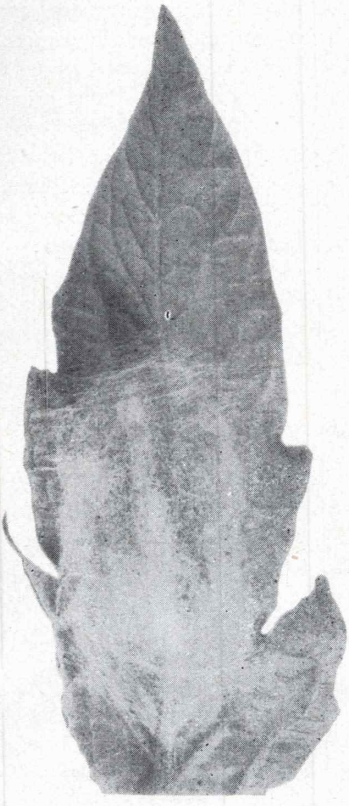

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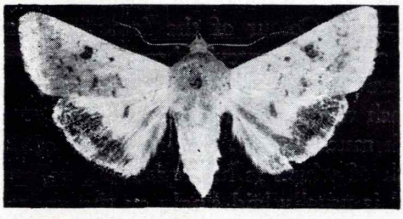

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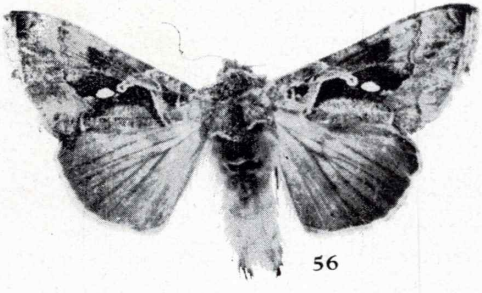

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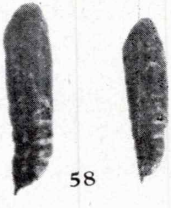

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Fig. 56—Looper-caterpillar: adult form. $\times 1\frac{3}{4}$.
Photo by R. I. Hughes.

Fig. 57—Looper-caterpillar: eggs on underside of leaf. Enlarged.
Photo by H. Drake.

Fig. 58—Looper-caterpillar: pupae. Natural size.
Photo by H. Drake.

Fig. 59—Looper-caterpillar: webbing over pupa on underside of leaf. Natural size.
Photo by H. Drake.

Fig. 60—Tomato-caterpillar: adult form. $\times 1\frac{1}{4}$.
Photo by R. I. Hughes.

(Fig. 56). When wings are stretched out as in the figure they measure about 1½ inches across. The moth, which flies by night, can lay up to 500 eggs (Fig. 57). These are white, about the size of a hole made by the point of a pin, and are laid singly, usually on the undersides of leaves. After hatching, which takes 7–10 days, caterpillars usually frequent the undersides of leaves and fruit, requiring 4–6 weeks to reach full growth. The brown pupa (Fig. 58) is enclosed in a webbing of white silken threads (Fig. 59) and can be found on the underside of a leaf or in some other sheltered place above ground. The adult moth appears in 10–14 days. The whole life-cycle occupies 7–9 weeks and there are probably several generations per year in the northern part of New Zealand. The insect overwinters in the pupal stage above ground in sheltered locations.

Tomato-caterpillar

Tomato-caterpillars vary in colour from light-green, pinkish or brown to almost black and are marked wtih alternate light and dark longitudinal lines. They are about 1½ inches long when fully grown. Adult moths (Fig. 60) have a wing expanse of about 1½ inches. Colour of the fore-wings varies considerably, the most common being a brown to greyish-brown with a series of dark, irregular transverse lines. There is a darker area towards the tip and a dark spot almost in the centre of each wing. Hind-wings are very light at their bases with the outer half of each much darker. The moths fly at dusk. Females may lay 500–1,000 eggs, each of which is hemispherical, yellowish, about half the size of a pin head, and is usually laid singly on the underside of a leaf. Hatching takes place in 7–10 days and caterpillars feed for 4–6 weeks before becoming fully grown. They then migrate to the ground and construct smooth-walled cells 3–5 inches below soil level, transforming there to dark-brown pupae or chrysalises. From these, adult moths emerge 10–25 days later. There are probably several generations a year. These insects overwinter as pupae in cells in the ground.

Control

Spray with D.D.T. or lead arsenate regularly after plants are set out, the number of applications required varying with local conditions. The aim should be to prevent insects establishing, as once this happens, control becomes difficult (see pages 85–96).

After harvesting, remove and destroy all old and dead plants so that resting places for pupae of the looper-caterpillar are destroyed.

Where tomato-caterpillars have been numerous, it is advisable to plough deeply in later winter and cultivate as much as possible before planting in order to destroy overwintering pupae in the ground.

STEM-BORER (*Gnorimoschema plaesiosoma* Turn.)

Importance and Type of Injury

This is one of the most serious pests. Affected plants wilt, and if their stems are sectioned they are found to have been hollowed out from approximately 6–8 inches above ground-level to about one inch below ground-level (Fig. 61). On dwarf varieties stems often break off near ground-level (Fig. 62). This damage is caused by small, dark-headed caterpillars with greyish-green or pink bodies measuring up to half an inch in length. If damaged stems are examined carefully, it will be found that caterpillars have, in places, eaten small holes to the outside (Fig. 62). Present throughout the Dominion, but does not appear to be troublesome south of Christchurch.

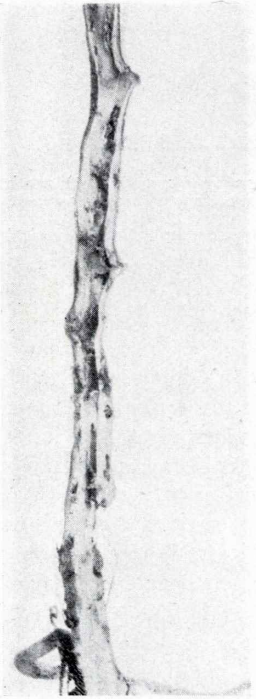

Fig. 61 — Stem-borer: section of stem of staked tomato plant showing burrowings of caterpillars. Note burrows in the middle and surface parts of stem. × ½.
Photo by L. H. Wright.

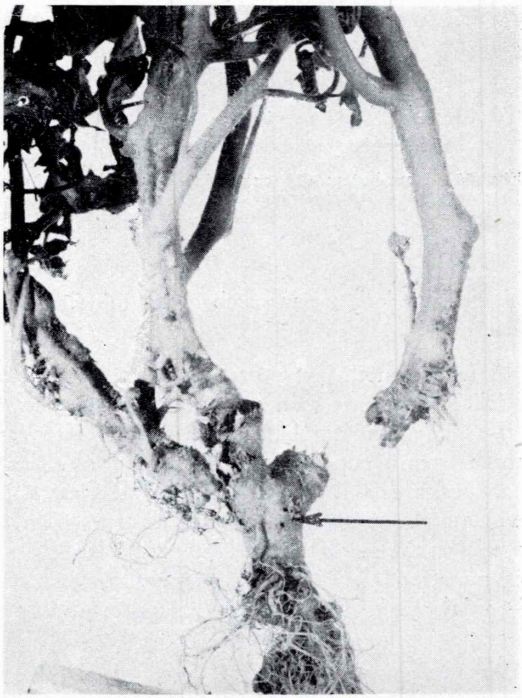

Fig. 62 — Stem-borer: note breaking of stem of dwarf tomato plant near ground-level and two small holes (indicated by arrow) bored to surface by the caterpillars.
Photo by L. H. Wright.

Appearance, Life-history and Habits

The adult is a small greyish-brown moth (Fig. 63) measuring approximately half an inch across outstretched wings; with wings closed it is about quarter of an inch from head to wing-tips. Fore-wings are narrow with a

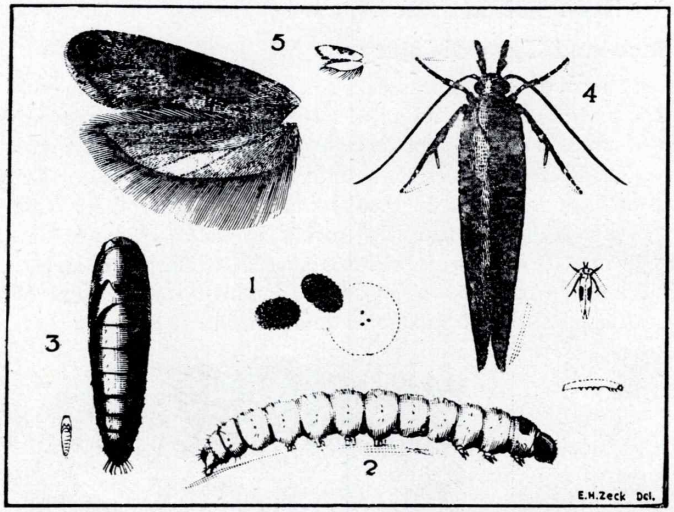

Fig. 63—Stem-borer: (1) eggs, (2) caterpillars, (3) pupa or chrysalis, (4) moth, (5) moth wings to show markings. The small figures in each case show approximate natural size.

From W. L. Morgan, by kind permission.

characteristic dark-brown patch in the middle of each. Hind-wings are much paler.

A female moth lays up to 300 white eggs (Fig. 63), microscopic in size, on foliage or stems soon after plants are set out in the spring. They hatch in 7–11 days and if plants are young and tender, caterpillars bore straight into the stems, but if plants are slightly older and tougher, caterpillars first enter the leaves and tunnel through to the leaf stalks, finally burrowing down these into the stems. The caterpillar stage (Fig. 63) occupies approximately 3 weeks in the summer, but may take 6 weeks in winter. When fully grown they pupate (Fig. 63) in the burrows made in the stem, and moths emerge 10–14 days later. Under New Zealand conditions there may be three or four generations per year.

Control

Spray with D.D.T. or lead arsenate from the time plants are set out in glasshouse or field (see pages 85–86). On large plants pay special attention to the basal 12 inches of the stem, because it is in this region that most insects gain entry.

As the pest can carry over to the next crop in old tomato plants and plant debris these should be collected and burned.

This moth can breed in potato plants, so that proximity to such a crop enhances the chances of infestation.

CUTWORM (*Agrotis ypsilon* Hfn.)

Importance, Type of Injury and Distribution

In some seasons, a considerable amount of damage from cutworms may occur when young plants are set out in the field, and although this may happen at any time of the growing season, it seems to be most noticeable in the spring. Plants are cut off at or near ground-level and will be found lying wilted on the ground. The damage is done at night, and during daylight the cause of trouble will not be visible. A search in the soil close to a damaged plant, however, will reveal the caterpillar responsible lying in a curled-up position just beneath the surface. Occurs throughout the Dominion.

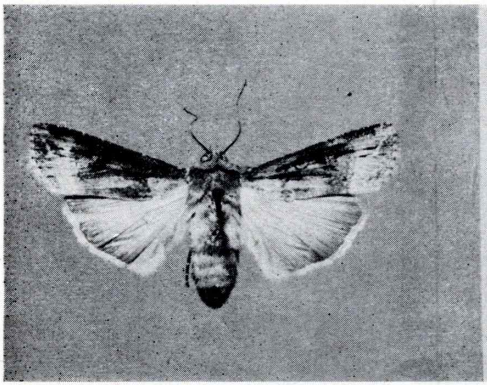

Fig. 64—Cutworm: adult form. Natural size. *Photo by R. I. Hughes.*

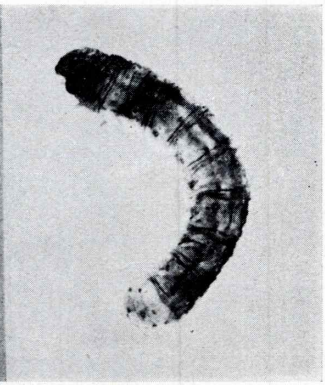

Fig. 65—Cutworm. × 1 1/3. *Photo by R. I. Hughes.*

Appearance, Life-history and Habits

There are several species of night-flying moths, the caterpillars of which are cutworms, the most common being *Agrotis ypsilon*. This moth is brown to greyish-brown with large areas of black on the fore-wings (Fig. 64), which are rather long and narrow. It is approximately $1\frac{3}{4}$ inches across outstretched wings. The moth flies at night and, during the day, hides amongst rough herbage, etc., such as weed growth. It would appear that eggs are laid on such rough growth, but they are also deposited on bare ground, especially that which is subject to periodical flooding. The light-grey caterpillar is plump and somewhat greasy-looking; when fully-grown it is approximately $1\frac{1}{2}$ inches long (Fig. 65). During the day it lies in a burrow 1–2 inches below the soil surface in a curled-up position and emerges at night to feed. Pupation takes place as a subterranean brown chrysalis.

It is likely that hibernation occurs in the chrysalis form.

Control

Clean cultivation and keeping down weed growth is important. Use of the Paris green or white arsenic bait (see page 87) will give good results.

VEGETABLE-WEEVIL (*Listroderes obliquus* Gyl.)

Importance, Type of Injury and Distribution

This pest is of rather sporadic occurrence, but may be troublesome in young plants, especially under glass. Plants will be found with tops eaten out or leaf stalks partly chewed through, so that leaves are left hanging (Fig. 66). The cause of damage is often a mystery because the weevil feeds only at night, hiding in the soil near the base of the stem by day. However, a search in the soil will reveal the grubs or adult weevils responsible. The weevil is widespread throughout the North Island.

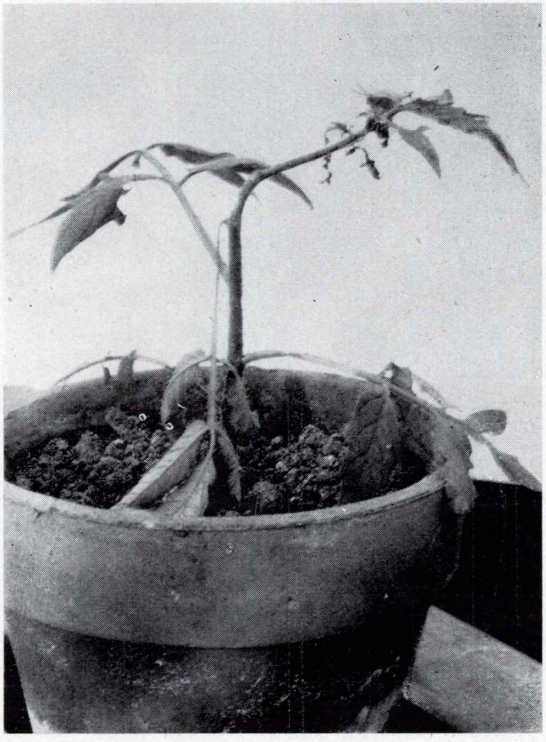

Fig. 66—Vegetable-weevil: young tomato plant with centre eaten out.
Photo by M. J. Dahlberg.

Appearance, Life-history and Habits

The grub (Fig. 67) is green to greyish-green with a blackish-brown head. When fully grown it is half an inch long, plump and legless, and when seen on the plant is rather sluggish in its movements. While young it remains on the plant throughout the day, but when older it can be found in this position

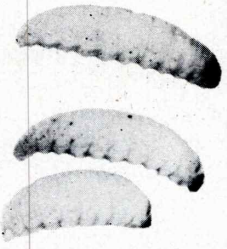

Fig. 67—Vegetable-weevil: grubs. × 2.
Photo by R. I. Hughes.

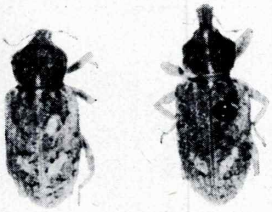

Fig. 68—Vegetable-weevil: adults. × 3.
Photo by R. I. Hughes.

only at night, daylight hours being passed in a curled-up position just beneath the surface of the soil adjacent to the plant stem. The adult (Fig. 68) is a dark-brown or greyish-brown weevil approximately one-third of an inch long, rather elongated and with a typical weevil "snout." On the back there are two obliquely placed, greyish-white, short lines which form a distinct V-shaped mark. The weevil is nocturnal in habit and hides under debris on the ground during the day. Females lay over 500 eggs in a season. These are broadly oval, greyish-black, and about one-quarter the size of an ordinary pin-head. They are laid on foliage and hatch in approximately 3 weeks. The grub occupies 80–90 days in reaching the full-grown larval stage, and when it has done this, it enters the soil to a depth of about 2 inches, constructs a smooth-walled earthern cell and pupates. The pupa is green, changing to reddish-brown just before the adult emerges after a period of approximately 21 days. This insect is peculiar in that over the hot summer months the only stage present is the adult weevil, which takes no food and lays no eggs during this period.

There is only one generation per year. In the Auckland district, adults may live for two years, egg-laying commencing each season in March.

Control

Lead arsenate spray at 3 lb. per 100 gallons water will control this pest (see page 85).

This weevil feeds on a number of weeds, such as mallow and cress, and the keeping down of weed growth generally is an important factor in control.

GRASS-GRUB, SUBTERRANEAN GRASS-CATERPILLAR AND WIREWORM

Importance, Type of Injury and Distribution

They are of economic importance only in field crops grown in land that has been broken out of grass. If present in sufficient numbers, any of these pests may cause damage to a crop by destroying roots. Infested plants are unthrifty, and where damage is severe, wilting occurs. Dominion-wide.

Appearance and Habits

Grass-grubs (Fig. 69) are white and are characteristically curled-up in the soil in the form of a "U." The head is brown, while the hindpart of the abdomen is usually dark in colour and somewhat swollen in appearance. When fully grown the grub is approximately 1 inch long. The adult is the common brown-beetle which is on the wing during November and December.

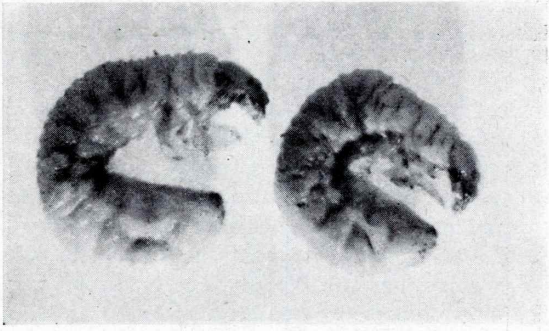

Fig. 69—Grass-grubs. × 2½.
Photo by R. I. Hughes.

The subterranean grass-caterpillar (Fig. 70) is the immature form of a moth. It is dark coloured and limp and may vary from 1½–4 inches in length. The head is usually black. Underneath portions of the body are lighter in colour than the upper surface. In cultivated land, it spends most of its time underground, feeding on roots of plants such as tomatoes.

Wireworms (Fig. 71) are immature forms of click-beetles. They are usually some shade of brown, shiny and tough in texture, hence their name.

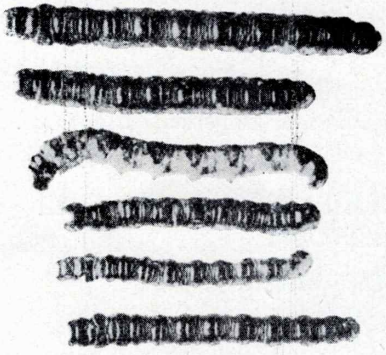

Fig. 70—Subterranean grass-caterpillars. × 2/3.
After Cockayne.

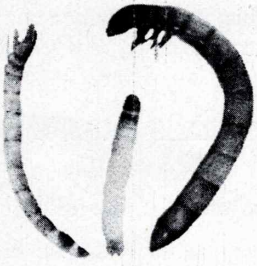

Fig. 71—Wire-worm: three different species. Natural size.
Photo by R. I. Hughes.

Control

When ground newly-broken from grass is being prepared for a tomato crop it should be inspected for the presence of these insects. If they are found, the soil should be worked as much and as often as possible before plants are set out, to expose the insects to birds and unfavourable conditions and to kill some mechanically.

Risk of infestation is greatest in light soils, and where such lea land is known to be infested, it should be avoided if possible, or else prepared well in advance of planting time.

SUCKING INSECTS

GREEN VEGETABLE-BUG (*Nezara viridula* L.)

Importance, Type of Injury and Distribution

This insect has appeared in New Zealand only within recent years. Both fruit and foliage of tomato are attacked. The skin of the attacked portion of the plant is pierced and the sap extracted from the plant cells in the vicinity of the punctures. On infested tomato plants tender young growth is distorted. Damaged fruit is mottled and unattractive in appearance. Heavy infestation causes a weakening of plants and a reduction in the quality and quantity of fruit. This pest has been found at New Plymouth, in the Northland, and the Whakatane-Opotiki area.

Appearance, Life-history and Habits

The green vegetable-bug* belongs to the family of insects commonly described as "shield-bugs." The adult is light-green, shield-shaped and approximately half an inch long and one third of an inch wide across the broadest portion (Fig. 72). The eggs are usually laid together in clusters on the host plant. They are cylindrical, flattened on top and rounded at the lower end and vary in colour from pale-yellow to reddish-brown. The immature forms of the insect are approximately oval in shape and may have colours of black, brown, green, crimson, orange, yellow or red on them at various stages of growth (Fig. 72).

The insect overwinters in the adult form. In New South Wales, Australia, it has been found that the eggs hatch in 5–8 days, and that the period from egg to adult averages 40 days. It is probable that there are several generations per season in New Zealand.

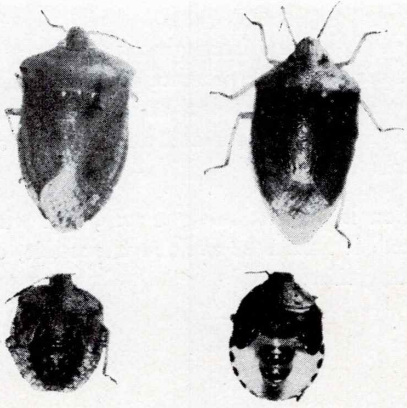

Fig. 72—Green vegetable-bug and native shield-bug.

Left: Green vegetable-bug. Upper: adult form. (Note line of three white dots on upper third. Lower: immature form.

Right: Native shield-bug. Upper: adult form. Lower: Immature form. × 2.

Photo by R. I. Hughes.

Control

As bugs congregate in shelter afforded by leaves, etc., it is necessary to remove all old tomato plants, destroy plant debris, and to keep down weed growth by clean cultivation. To prevent overwintering of adults, the above measures should be carried out with particular thoroughness in the autumn.

Where this pest is troublesome, spray with D.D.T. (see page 86).

*As this insect may be confused with a large, green, native shield-bug (*Zangis amyoti* White) which is not a pest of tomatoes, the following points of separation are given: As shown in the illustration (Fig. 72), the adults differ in shape and the green vegetable-bug has three small white spots in a row on the border of a transverse groove near the front of the body. At each end of this groove there is a minute black spot which can be clearly seen with a hand-lens.

WHITE-FLY (*Trialeurodes vaporariorum* Westw.)

Importance, Type of Injury and Distribution

This pest is sometimes important under glass.

Infested plants become pallid, assume an unthrifty appearance and suffer loss of vigour. Foliage becomes mottled and in severe cases may wither and die. If infested plants are disturbed, myriads of small white flies rise in the air, and examination of undersides of leaves shows many tiny, flat, scale-like organisms that are the immature stages of the pest. While the insects are feeding, they exude quantities of honey-dew, which, in time, forms a sticky, varnish-like film over all parts of the plant, including the fruit. A black-mould fungus develops on the honey-dew, giving plants a characteristic unsightly sooty appearance. In severe cases it may even be necessary to wipe fruit before marketing. Occurs throughout the Dominion.

Appearance, Life-history and Habits

The adults (Fig. 73) are small moth-like insects approximately one twenty-fifth of an inch long, covered with a fine, white, powdery substance. Usually they remain on the undersides of the leaves, but on hot days may be seen fluttering about the plants. The female lays eggs on undersides of

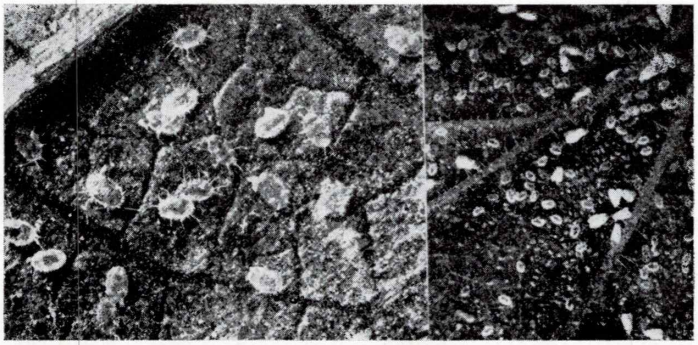

Fig. 73—White-fly.

Left: adult and immature forms. × 2. Right: scale-like immature forms. Enlarged.

From E. O. Essig: Insects of Western North America. *Copyright, 1926, by the Macmillan Company and used with their permission.*

leaves and during the summer these hatch in about 14 days. The small, scale-like insect that emerges from each egg increases in size until at full growth it is roughly oval, flattened and of a glassy appearance. If examined with a strong hand-lens, it is seen to be decorated with a fringe of wax and to possess several long, glassy spines on the upper surface (Fig. 73). Finally, the adult emerges through a slit in the scale-like structure. The length of the life-cycle varies with the temperature, but in summer occupies about a month.

White-flies have a habit of congregating together while feeding, and this, combined with the inactivity of the immature forms, prevents the pest from sprading rapidly through a house. At first it is usual for only a few plants to be attacked, but infestation gradually spreads until the whole crop may become infested.

Control

Care should be taken to prevent white-fly becoming established in the house. Examine young plants thoroughly before introducing them; it is possible that some may be carrying enough individuals to start an infestation.

To control, spray or fumigate with nicotine sulphate (see page 97).

GREEN APHIS (*Macrosiphum euphorbiae* Thos.)

Importance, Type of Injury and Distribution

Occasionally green-aphis, also known as green-fly, occurs as a pest in glasshouses. The young, tender, growing parts of plants become covered with small green insects which, on magnification, appear as in Fig. 74. Their feeding produces malformation and stunting of shoots and inward rolling of leaves. In addition to causing damage to plants by feeding, green-aphis is responsible for the transmission of cucumber-mosaic (see page 32). Occurs throughout the Dominion.

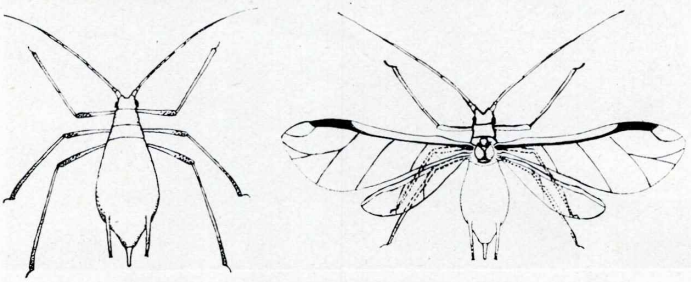

Fig. 74—Green-aphis. Left: wingless form. Right: winged form.
Del. W. Cottier.

Appearance, Life-history and Habits

There are two forms of adult in the female of these aphids. One is wingless and the other has four wings (Fig. 74), the later serving to spread infestation. Both forms are green and are approximately $\frac{1}{8}$ inch long; they have long antennae and move slowly by means of their comparatively long thin legs. Aphids produce living young and, as they reach maturity in a short time, colonies increase rapidly when conditions are favourable.

Control

Spray or fumigate with nicotine sulphate (see page 87).

INSECTS THAT RASP AND SUCK

THRIPS (*Hercinothrips bicinctus* Bagn.)

Importance, Type of Injury and Distribution

This insect causes damage to tomato fruit in the field. Injured fruits show whitened corky areas on the surface; as the fruit grows, these develop into small cracked areas as shown in Fig. 75. This pest has been found only at Patumahoe and Auckland.

Appearance, Life-history and Habits

The adult thrips is a slender, dark-brown insect approximately one sixteenth inch long. On examination with a hand-lens, the light-coloured wings show two dark bands across them; the wings are also fringed with long hairs.

The female lays her eggs just within the plant tissue. These produce young forms which are cream to light yellow in colour and wingless. All stages may be found together on damaged portions of the plant.

Control

Spray with nicotine sulphate or D.D.T. (see pages 86 and 87).

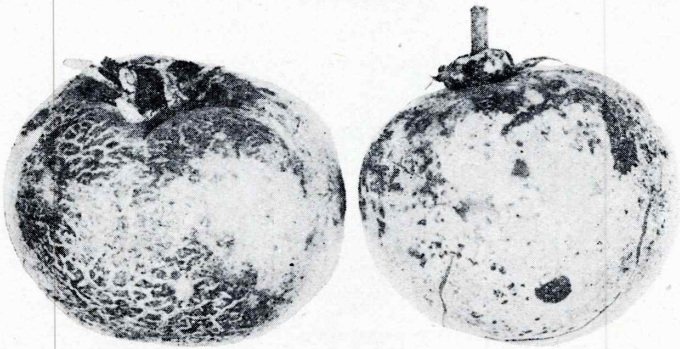

Fig. 75—Thrips: damaged tomato fruit. × ¾.
Photo by M. J. Dahlberg.

MISCELLANEOUS

ROOT-EELWORM (*Heterodera marioni* Cornu)

Importance, Type of Injury and Distribution

This pest is one of the most important under glass.

Infested plants may be stunted and are usually paler in colour than healthy ones. They present a general sickly appearance and readily wilt under dry conditions. In some cases plants may grow normally at first, but eventually show symptoms. The foliage dies at the edges, all growth stops and the plant collapses or dies slowly. Such plants have numerous galls or nodules on the roots (Figs. 76 and 77), these being characteristic of eelworm infestation. Present throughout the Dominion.

Appearance, Life-history and Habits

The adult female of the eelworm measures approximately one twenty-fifth of an inch long, while the male eelworm is invisible to the naked eye. It is pear-shaped and just large enough to be seen with the naked eye as a tiny, glistening, white globular body. It produces on the average 300–600 eggs. Where the female is near the surface of the root the egg masses may be pushed through the tisue to the outside and the larvae escape into the soil. When, however, it is deep in the tissue, egg-laying may be hindered, with the result that the eggs remain in the body and the young worms escape only on hatching. The young forms either settle in another part of the same root, or travel through the soil to another root of the same or a different plant. The new root is entered near the growing tip. In its new position the worm grows to maturity, this period occupying 3–5 weeks in summer, according to soil temperature.

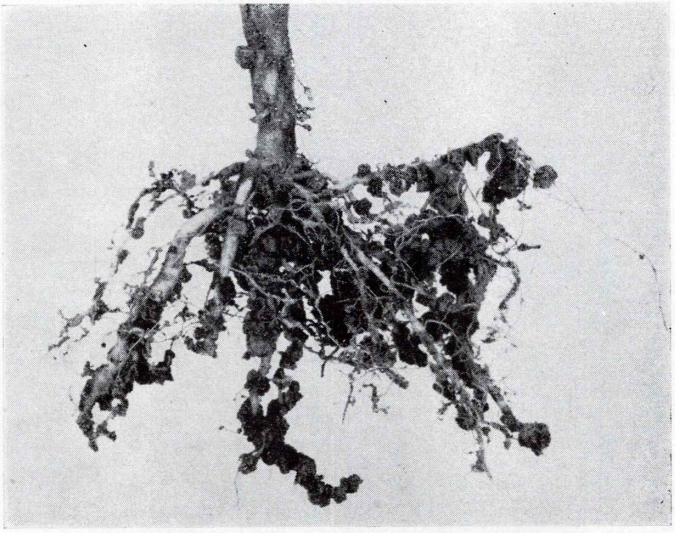

Fig. 76—Root-eelworm: galls on roots of tomato plant. Heavy infestation. × ½.

Photo by L. H. Wright.

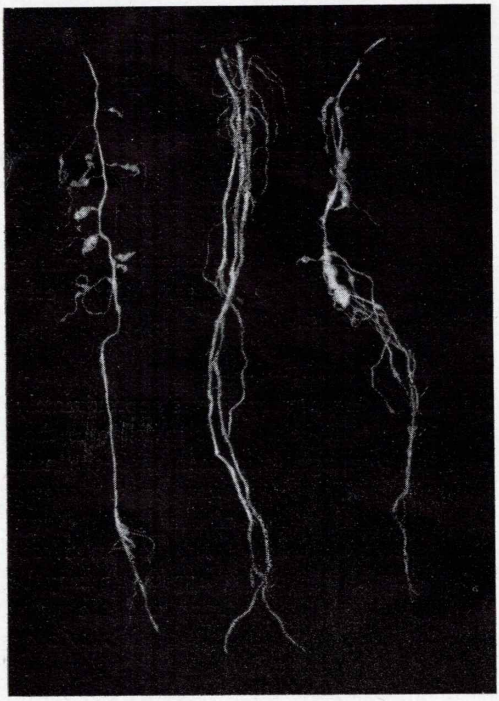

Fig. 77—Root-eelworm: galls on roots of tomato plant. Moderate infestation. × ½.

Photo by L. H. Wright.

The winter is passed in egg or larval stage in the soil.

Eelworm is generally a more important pest in light soils. It also breeds faster at higher temperatures, hence it is of greater importance as a pest in glasshouses.

Control

In Glasshouses

(a) By steam disinfection (see page 92).

(b) By chemical disinfection (see page 96).

(c) By changing the soil. This is laborious and should be resorted to only where steam or chemical disinfection is not practicable. Soil should be removed to a depth of one foot and replaced with soil known to be clean. It is advisable to wash wood or brickwork in contact with infested soil with a hot coal-tar disinfectant.

In the Field

Generally steam or chemical sterilisation is not economical on a large field scale, although there are cases where one of these methods can be used profitably.

Growing of tomatoes on the same land for two successive years should be avoided. If a grower produces his own plants or takes adequate precautions when buying from outside sources, he may not be troubled with eelworm for many years, but once the pest appears it increases rapidly if successive tomato crops are grown.

If eelworm becomes established, it is necessary to practise crop rotation. The only crops resistant to the pest are grasses, including barley, wheat and oats. To eliminate the pest, infested land should be put down in grass for three or four years. If this is not feasible, the growing of barley, wheat or oats as a cover crop for a season will sufficiently reduce infestation to allow another tomato crop to be grown.

The following vegetables are tolerant to eelworm and will give a profitable crop even when grown in infested soil: asparagus, onion, cabbage, cauliflower, celery, sweet corn, parsnip, carrot, radish, rhubarb, spinach, and turnip. These crops may be grown in the rotation, but as they do not reduce the eelworm population it is necessary to precede tomatoes with grass or cereals.

General

To make sure that all plants are free from infestation when set out, they should be examined carefully for root nodules. To ensure freedom from eelworm, growers should raise their own seedlings and grow them in disinfected soil.

In either glasshouse or field, infested plants should be dug with infested roots attached and burnt. Infested plants should not be thrown on compost heaps, as eelworm may be distributed to clean soil from this source. It also spreads readily from infested ground on implements, boots, etc. To destroy the pest, remove soil from implements and boots and thoroughly dry, or dip them in a strong solution of a coal-tar disinfectant.

TOMATO-MITE (*Phyllocoptes lycopersici* Tryon.)

Importance, Type of Injury and Distribution

This pest is of sporadic occurrence, but it can cause severe damage under glass. It has also been recorded as damaging outdoor tomatoes in the Auckland and Tauranga districts.

Infestation may occur at any stage of growth, but is usually not apparent until the plants are well established. Stems develop a smooth, bronze-coloured appearance, caused by injury to the epidermis and destruction of epidermal hairs. Infested plants are stunted and pallid. The more severely attacked

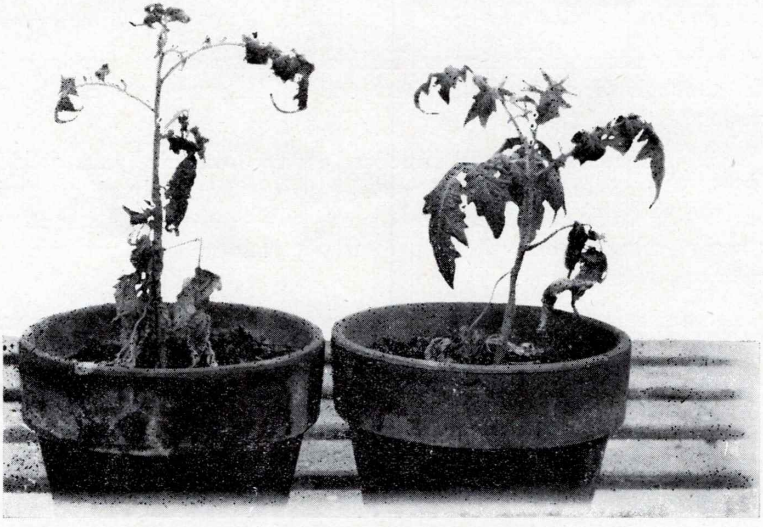

Fig. 78—Tomato-mite: young plants showing withering and curling of foliage.
Photo by M. J. Dahlberg.

leaves wither and die. Plants which are young at time of infestation are usually severely damaged and eventually die (Fig. 78). On older plants damage may not be so severe, but they are usually less vigorous and their yield reduced. Fruits may also be attacked, a rough brown russet forming on the skin. As the fruit enlarges, this russetted skin becomes cracked and fruits may present an appearance as shown in Fig. 79. The mite has been found in the North Auckland, Auckland, Hawke's Bay and Bay of Plenty districts.

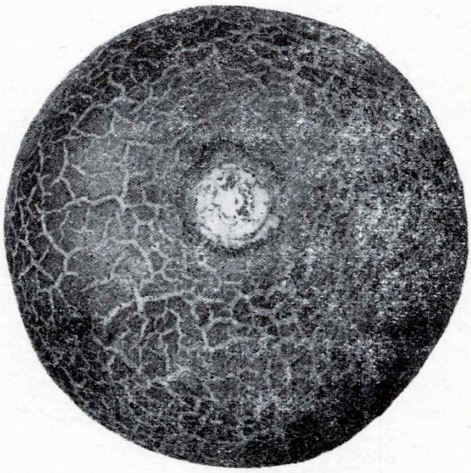

Fig. 79—Tomato-mite: damaged fruit showing cracks on skin. Natural size.

Photo by W. E. Barnard.

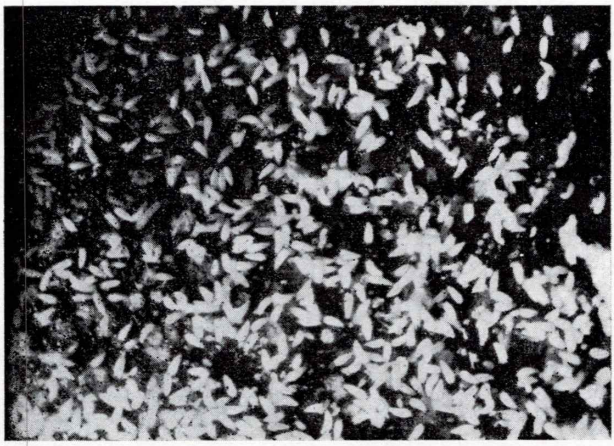

Fig. 80—Tomato-mite: mites on surface of plant. Note spherical eggs amongst mites. × 30.

Del. W. Cottier.

Appearance, Life-history and Habits

The mite is very small (approximately 1/250 inch. long) and can be seen clearly only by magnification (Fig. 80). It is elongated and moves by means of four legs placed at the head end of the body. The colour is cream to a very light yellow in the adult and somewhat lighter in the immature stages. Mites congregate on the surface of plants in large numbers and to the naked eye have the appearance of fawn-coloured dust. The eggs are about one quarter the size of the adults. They are round, white and shining, and are deposited

abundantly on the surface of infested areas. These mites pass through their life-cycle rapidly and a small initial infestation may become acute within a few weeks.

That they can overwinter in an unheated glasshouse seems probable, since live mites have been found in the spring on old plants of an abandoned crop which had been heavily infested in the previous autumn.

Control

The most effective method is to fumigate houses with nicotine sulphate (see page 87). Where a house is insufficiently gastight to allow of successful fumigation, the plants should be sprayed with nicotine sulphate (see page 87).

Carry-over from one crop to another occurs most readily in houses where two crops are grown each year. Under these conditions the interval between the removal of an infested crop and planting of the next should be as long as possible. Care should be taken to remove all old plants, and whilst the house is empty, to cultivate the soil thoroughly. As a precautionary measure, fumigation or spraying is advisable as soon as the new crop is established.

Once established, mites spread rapidly to healthy plants, and since they are relatively inactive, it would appear that the principal agents of distribution are the hands and clothing of workmen. They may be introduced into glasshouses, in which mites have not previously been present, on seedlings from infested nurseries or by visitors from infested houses. Precautions should be taken to prevent distribution of mites by these methods.

THE RED-LEGGED EARTH-MITE (*Halotydeus destructor* Tuck.)

Importance, Type of Injury and Distribution

The effect of large numbers of this mite on young tomato plants is very severe (Fig. 81). The mites feed by piercing the leaf tissue and sucking the sap. At the point of attack the plants become whitened or silvered due to

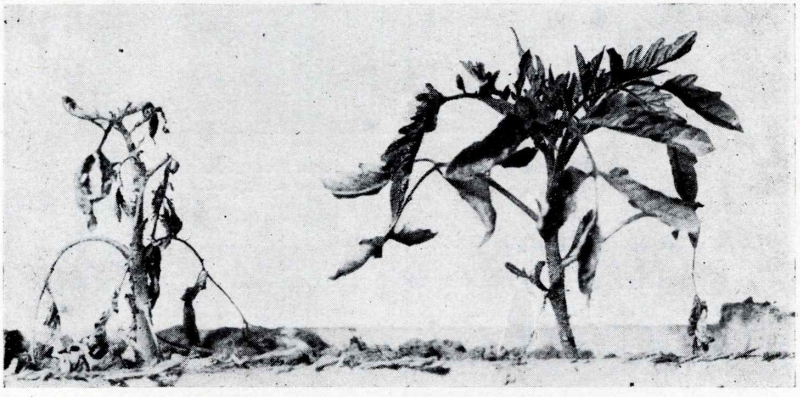

Fig. 81—Red-legged earth-mite.
Left: plant severely damaged. Right: healthy plant.
After Dumbleton.

the withdrawal of the cell contents. In severe cases this withdrawal of sap is so heavy that the plants collapse and young transplants may wither away in a few days.

Damage seems to be heaviest on young plants just after they are transplanted into the field. Later, when growth hardens, plants are not so severely attacked. The mite has been found only in the vicinity of Napier and at Wairoa and Matawhero (near Gisborne).

Appearance, Life-history and Habits

The body of the adult mite is a dull, velvety-black and approximately 1/25 inch long (Fig. 82). The mites are very rapid in their movements.

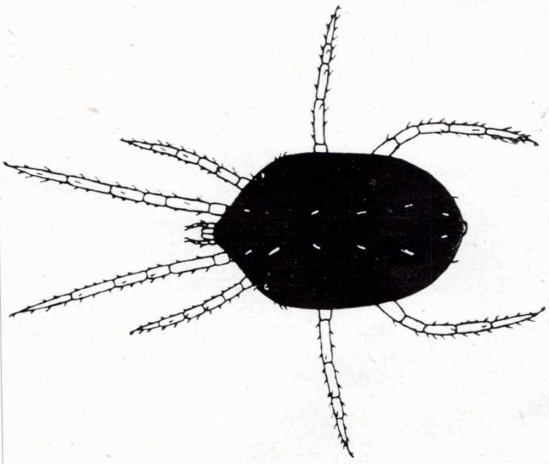

Fig. 82—Red-legged earth-mite. × 34.

Del. W. Cottier.

They can be recognised by the reddish colour of the legs, from which is derived the common name.

This pest is active only during the autumn, winter and spring. During the summer only the egg stage is present. In the autumn, cool temperatures and rainy weather cause the summer eggs to hatch, and in about 60 days the resulting mites are mature and laying eggs. Each mite may lay 50 to 100 eggs, which are barely visible. As many are usually laid together, the masses are easily recognised by their yellowish to orange colour. These eggs are laid on the undersides of the leaves of many kinds of plants, mostly weeds. There are three generations per year. It has been found that the largest numbers of mites occur in the spring, during September and October.

They tend to be gregarious and cluster together when feeding. They are most active in the evening, early morning and in dull weather.

The red-legged earth-mite seems to thrive best on light sandy soils in areas that have a dry summer and a good winter rainfall.

Control

Effective control of the mite can be obtained by spraying with D.D.T. (see page 86) or nicotine sulphate (see page 87).

On infested ground it is recommended that treatment be given as soon as plants are set out in the field, as very severe damage can be done in the first few days after transplanting. Subsequent applications should be made every 10 to 14 days and continued until plants harden and can withstand attack. If D.D.T. is used, it is probably an advantage to apply enough spray to cover the ground beneath the plants.

Deep ploughing in early spring and late summer to bury as many as possible of all stages should reduce subsequent infestations.

As the mites feed and breed on many low-growing, broad-leaved weeds such as Scotch thistle and wild turnip, it is important to clear areas of waste ground such as headlands, fence-lines and ditches.

SLUGS AND SNAILS

Importance, Type of Injury and Distribution

These are often troublesome in newly-planted crops. They chew pieces out of the plant and usually leave a trail of silvery slime on the host, indicating the cause of the injury. Occurs throughout the Dominion.

Appearance, Life-history and Habits

Slugs and snails are well enough known to require no description for recognition purposes. They are active under wet or humid conditions and consequently are troublesome at night, particularly in spring and autumn. In winter and in dry periods they remain quiescent.

The eggs of slugs and snails are spherical, colourless, jelly-like and semi-transparent. They are laid in clusters in the soil or under seed-boxes, flower-pots or decaying vegetation, etc., in moist situations.

Control

The best controlling agent for slugs and snails is a bait made from bran and "Meta" (a proprietary solid fuel) or the chemical metaldehyde (see page 88). Where "Meta" or metaldehyde are non-procurable, the Paris green bait (see page 87) can be used, but is less effective.

Good results are also obtained by the use of dehydrated copper sulphate (see page 88).

SLATERS

Importance, Type of Injury and Distribution

Slaters, which are also known as woodlice, are of importance sometimes in glasshouses, where they nibble pieces out of stems and leaves and sometimes roots.

Appearance, Life-history and Habits

These organisms are not insects, but belong to the family that includes the crabs and crayfish and are really land crustaceans. Slaters (Fig. 83) are grey in colour, about $\frac{1}{2}$ inch long when fully grown and are oblong-oval in shape. They are segmented, convex on top and flat on the underside, and are

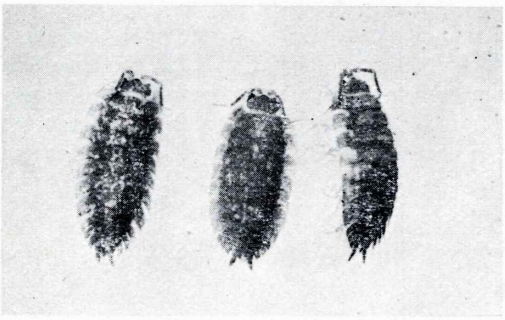

Fig. 83—Slaters. × 2.

Photo by R. I. Hughes.

provided with 7 pairs of legs. Eggs are produced in spring and these are carried on the underside of the body of the female until they hatch. Slaters are nocturnal creatures and prefer moist situations. They feed normally on decaying vegetable matter, but will also attack growing plants.

Control

A dust containing 5 per cent. active D.D.T. sprinkled in places frequented by slaters provides an effective control. They can also be controlled by the use of Paris green poison bait (see page 87), or a Paris green and dried blood mixture (see page 88).

In dealing with slaters, it is important to remove heaps of decaying vegetable material or other rubbish such as old sacks or pieces of rotted wood, as these provide refuge for the pests.

CONTROL MEASURES

CONTROL of nearly all the major pests and diseases of tomato crops can be achieved by any grower who takes adequate precautions. Only in a few instances, e.g., tomato spotted-wilt virus, tomato-canker of field crops and certain physiological diseases, are there no effective means of control.

Success depends on the application of three main practices, viz., eradication of sources of infection, prevention of infection and prevention of spread. Recommendations are given under three main headings—cultural practices, plant therapeutants, and soil disinfection.

CULTURAL PRACTICES

USE OF DISEASE-FREE SEED

Three serious diseases, bacterial-canker, tobacco-mosaic, and tomato-streak, are commonly carried with the seed of tomatoes and several other diseases are occasionally seed-carried. Seed should, therefore, be saved only from healthy plants. As it is not always possible to recognise certain diseases on fruiting plants, it is necessary to use a method of seed extraction which will eliminate infection. This is most satisfactorily done by the acid extraction method described below.

Acid Extraction of Tomato Seed

Cut well-ripened fruits so that each seed compartment is opened, and squeeze pulp into a wooden barrel or bucket. Metal containers should not be used, as the reaction of acid with the metal weakens the solution and causes discolouration of seed. To pulp from every 5 lb. of fruit add one fluid ounce of concentrated hydrochloric acid. Mix the acid thoroughly into the pulp and allow to stand for three hours, stirring at intervals. Wash thoroughly by forcing water into the mixture, a procedure which assists in separating the seed from the seed sacs and other unwanted material. Allow seed to settle and decant off water. Repeat the washing process until all seed sacs, light seeds and fleshy material is removed. Strain clean seed through muslin, and dry as quickly as possible by spreading thinly on newspaper. Do not allow the damp seed to come in contact with metal as reaction of any remaining acid causes discolouration. Acid extraction not only eliminates seed-borne diseases, but yields a bright seed sample with high germination.

Seed Treatment with Acidulated Mercuric Chloride

When using seed of unknown history, it should be soaked for five minutes in acidulated mercuric chloride solution (1 g. mercuric chloride dissolved in 2·5 ml. concentrated hydrochloric acid added to 2,000 ml. water). After treatment it should be dipped in skimmed milk and dried.

PRODUCTION OF HEALTHY SEEDLINGS

To secure healthy crops it is essential that seedlings are well grown, hardy and free from disease. In order to achieve this objective it is necessary to:—

(a) Disinfect soil and seed-boxes (see pages 92–99) to destroy diseases.

(b) Avoid excess watering to prevent soft growth.

(c) Use nitrogenous fertilizers sparingly to avoid soft growth.

(d) Provide ample lighting to prevent drawing-up.

(e) Fumigate propagating houses with nicotine to destroy insects (see page 87).

(f) Harden off plants gradually, commencing when they are approximately 4 inches tall.

(g) When purchasing plants, examine them carefully for presence of disease on leaves, stems and roots.

HANDLING OF PLANTS

As spread of a number of diseases takes place during handling of plants, the following precautions should be taken:—

(a) Wash hands before handling plants for any purpose.

(b) Handle plants as little as possible.

(c) When lateralling, snap off laterals by holding only the portion to be discarded.

(d) Avoid injurying plants when tying, staking, etc.

WATERING OF GLASSHOUSE CROPS

Excess watering is one of the major causes of rapid development of leaf-mould and late-blight during early stages of growth. The soil should be well watered before plants are set out and further watering delayed until they begin to show signs of slackening in growth rate.

VENTILATION OF GLASSHOUSE CROPS

High humidity favours the development of leaf-mould and other fungous diseases. As humidity can be lowered by ventilation, houses should be ventilated as freely as possible consistent with maintenance of growth. Humidity becomes greatest at night, so as soon as temperatures permit, ventilation in the morning should be practised.

CROP HYGIENE

By the application of sound hygienic measures much can be done to keep diseases in check and prevent spread. The following measures are recommended:—

(a) Remove and destroy infected plants. This is most important during early stages, but may become uneconomic later in the season.

(b) Eradicate volunteer potato plants which may carry late-blight and verticillium-wilt (see pages 4–9).

(c) Destroy weeds and garden escapes, many of which carry diseases and pests.

(d) At the end of the season, collect and destroy all top growth and roots of old plants. These should not be composted.

(e) In the glasshouse, hose down walls of house and destroy old strings.

(f) Where possible, practise crop rotation to avoid overwintering of soil organisms.

(g) In glasshouses where soil-borne diseases have become serious, and it is not possible to steam sterilize, it is sometimes economic to replace the soil. All soil to a depth of 12 inches should be removed and replaced with clean soil from land which has not been in tomatoes or potatoes for a number of years, preferably from pasture.

PLANT THERAPEUTANTS

Under each disease or pest the appropriate treatments for control have been given. To obtain successful results, it is important that growers understand the general principles involved in disease control by therapeutants together with the uses and methods of preparation of fungicides and insecticides.

There are two main objectives in pest or disease control. In the first, a spray is applied to the plants for the purpose of *preventing* infection. In the second, treatments are used to *eradicate* diseases or pests from the plants. These two objectives should be clearly understood, since it is useless to expect a protective treatment to be effective once diease has become established. Alternatively, it is wasteful to use an eradicant treatment in the absence of the disase or pest to be controlled. All fungicides and many insecticides are protective. Some insecticides are eradicant, being used only where infestations occur, e.g., against green-aphis, tomato-mite and white-fly. It is in soil disinfection that eradicant treatments are principally used. These are discussed in a later section (see pages 92–100).

Disease and pest control would be simple if it were possible to ignore the possibility of plant damage. This factor alone prohibits the use of many materials and even those which are employed have to be used with care. Through incorrect usage of sprays, growers may cause greater reduction in crop yields than is likely to occur from the disease or pest itself. In many instances it is better economy to use a more costly material than to economize on a cheaper material which may damage the plants.

Where eradicant sprays are required, e.g., against an infection of white-fly, the need for treatment is self-evident. However, where protective sprays are called for, e.g., to prevent infection by late-blight, growers will have to make their decision on the necessity of spraying from previous experience or local advice. Thus in some districts infection by late-blight in glasshouse crops is almost unknown, consequently control measures are uneconomic. In other areas, Auckland, for example, spray treatments are necessary as an insurance against the possibility of total loss of crop.

In control of diseases of glasshouse crops, spray treatments alone cannot be expected to give effective control. It is equally important that cultural operations be carefully attended to, particularly in regard to humidity as affecting the development of late-blight and leaf-mould diseases.

SPRAY APPLICATION

Sprays are applied by means of force pumps of various kinds from hand-operated knapsack or bucket pumps to power-driven outfits used on portable trailers or as stationary units.

Knapsack and Bucket Pumps

For small areas or for glasshouse crops knapsack sprayers, though slow in operation, are quite effective. They are inefficient on larger areas, since in attempting to spray the crop in a reasonable time inadequate spray coverage usually occurs. The use of bucket pumps is restricted to home gardeners and to growers of glasshouse crops.

Mechanical Pumps, Hand-pulled

There are available several types of small outfits, the pumps of which are driven by benzine engines. Mounted on wheels, they can be taken between rows of staked tomatoes or along the centre pathway of a glasshouse. These outfits produce a pressure of approximately 200 to 250 lb. per square inch and have a spray tank holding about 15 to 20 gallons of mixture. Although not intended for use on large areas, they are much more effective than knapsack sprayers for glasshouse work and for staked plants out of doors.

Mechanical Pumps, Tractor or Horse-drawn

These outfits are designed for medium or large areas of outdoor crops. Pumps are driven by a power " take-off " from the tractor or else are provided with a separate petrol engine. Pump, engine and mixing-tank are mounted on a four or preferably a two-wheel trailer. Adjustment is usually provided for varying the width between wheels. In smaller outfits the pump is driven from the wheel of the trailer. In another type of unit, suitable for crops of staked tomatoes, the spray pump and mixing tank is built on to a small tractor.

Fixed nozzles are set on a boom in such a manner that the crop is sprayed without attention from a hand operator. For crops of dwarf tomatoes this method has the advantages that spraying can be completed rapidly and with considerable saving in labour. To obtain efficient coverage, however, care is required in obtaining the correct nozzle settings. Excessive speed of travel is to be avoided, since this is one of the major faults leading to inefficient spray coverage and in consequence poor disease control.

On dwarf tomatoes several rows can be sprayed at one time, depending on the width of spray boom. On staked crops, however, speed of spraying is reduced, since the outfit has to be driven between each row of tomatoes. In spite of this, considerable saving in time can be effected as compared with hand-operated pumps. Nozzles have to be carefully adjusted and the number in use increased as the plants grow.

Stationary Outfits

The method here is to locate the pump in a convenient place and to drive the spray through pipes to taps provided with connections for the spray hose. There are several advantages in the method, which is applicable mostly to glasshouse crops. The use of an electric motor for driving the pump does away with mechanical faults often associated with petrol engines. Spray tanks can be of any size, so that a single mixing is often sufficient to complete the spray treatment. If necessary, two or more operators can spray at the one time.

Stationary systems can also be employed with staked or dwarf outdoor crops. A limiting factor is the need for laying pipes which may have to be installed in different positions each year. Pipes are usually placed underground for permanent installation, but can be left on the surface or carried overhead. Taps are located at the ends of rows or at points along a row. Hoses of up to 120 feet can be employed, but they have to be handled carefully to avoid damage to plants.

Further details of stationary installations or of any of the portable outfits discussed above can be obtained from any of the commercial firms dealing with spray equipment.

Dosage Rate of Spray

The volume of spray required to cover a given area of tomato crop is influenced by so many variable factors that a specific recommendation covering

all conditions is impossible. It is estimated that with a power-driven outfit, approximately 300 gallons of spray per acre are required for a fully-grown outdoor crop of dwarf or staked plants. This estimate will vary with type of spray apparatus, vigour of plants, width of rows, etc. Under all conditions, efficiency of coverage should be checked by examination of plants after spraying and any necessary adjustment in nozzle settings or speed of spraying made accordingly.

DUST APPLICATION

Dust treatments for control of pests and diseases are not practicable in tomato crops. Although some pests might be controlled, for others spray treatments are necessary. For fungous diseases, none of the present dust treatments are comparable in efficacy with sprays. Dehydrated copper sulphate dust, however, when dusted over the soil surface, is an effective controllant of slugs and snails (see page 88). Also a 5 per cent. D.D.T. dust applied in a similar manner may be used for control of slaters (see page 88).

FUNGICIDES AND INSECTICIDES

In the following pages fungicides and insecticides are discussed, and recommendations given for their use in disease and pest control. Successful control is largely influenced by the quality of materials used in various proprietary brands of spray concentrates. As a guide to growers, a list of certified fungicides and insecticides is given on page 104. Growers are advised, however, to refer to current lists which are published in *The Orchardist of New Zealand* every six months by the Plant Diseases Division, Department of Scientific and Industrial Research, Auckland.

Fungicides

Bordeaux Mixture

The most important fungicide used for protecting tomato crops against attack by late-blight and septoria-spot. It is essential that the mixture be freshly prepared according to the directions given below.

Ingredients required are bluestone (copper sulphate) and hydrated lime (slaked lime). Dissolve the required amount of bluestone in a wooden barrel or glass jar by suspending it in a bag just dipping below the surface of the water. The bluestone will dissolve more rapidly if hot water is used. Mix the required amount of hydrated lime to a thin paste with water in a bucket. Fill the spray tank three parts full of water and add the hydrated lime through a strainer. Whilst thoroughly agitating the hydrated lime suspension, pour in the solution of bluestone. Add sufficient water to make up to the final volume and the mixture is ready to use. Alternatively the bluestone solution can be added first. Under no conditions should the concentrates of hydrated

lime and bluestone be mixed before one or the other has been diluted. If the mixing vessel or tank is iron it is preferable to add the hydrated lime first. Bluestone corrodes iron, but after it is mixed with lime corrosion is negligible.

In practice, dilutions are recommended as formulae, e.g. 6—8—100, which means six pounds bluestone, eight pounds hydrated lime, and 100 gallons water. The 6—8—100 mixture (i.e., 3—4—50) is the standard mixture for control of late-blight on outdoor tomatoes. Slight variations are sometimes used, e.g. 10—10—100, but are of no advantage and may cause increased plant damage. For glasshouse work, a mixture of 3—4—100 is sufficient to control late-blight under normal conditions of management.

Failure to secure control of late-blight with the above mixtures can usually be traced to one of the following conditions:—

1. Inefficient application of sprays whereby portion of fruit or foliage is not covered.
2. Allowing disease to become established before commencing the application of Bordeaux sprays.
3. Intervals between sprays too long, particularly during wet weather in outdoor crops.
4. In glasshouse crops, high humidity brought about by excessive watering and inadequate ventilation.

In a crop in which late-blight has become established and in which wet or humid conditions favourable to development of the fungus continue, there is little chance of eradicating late-blight with Bordeaux mixture or any other fungicide.

Treatments recommended above will also control septoria-spot and give partial control of leaf-mould.

Bordeaux mixture tends to harden plants and may cause leaf-burn and distortion of foliage. Resultant loss in vigour reduces yields (see later under Bordeaux substitutes). Bordeaux mixture can be combined with lead arsenate, D.D.T., Shirlan A.G. or nicotine sulphate. Soap should not be added to Bordeaux mixture (see under nicotine sulphate, page 87).

Burgundy Mixture

Similar to Bordeaux mixture except that washing soda replaces hydrated lime. It is just as effective as Bordeaux mixture, with the advantage that it does not leave such a conspicuous residue. Since hydrated lime is not used, the damage caused to pumps from grit frequently present in the lime is avoided. Burgundy mixture has the serious disadvantage that it cannot be combined with lead arsenate because of the risk of foliage injury through production of soluble arsenic.

Methods of preparation and quantities to be used (washing soda at equivalent weight to hydrated lime) are similar to those for Bordeaux mixture.

Bordeaux Substitutes

A group of copper sprays which are essentially different from Bordeaux mixture. They are not to be confused with so-called Bordeaux powders. The latter are inferior materials often consisting of a mixture of powdered bluestone and lime and cannot possibly be used to prepare Bordeaux mixture, in which the bluestone has to be dissolved separately from the lime.

Two types of Bordeaux substitute at present certified consist of copper oxychloride and copper oxide. The former is a blue powder containing 50 per cent. of copper, and the latter is red-brown in colour and also contains 50 per cent. copper. (See certification list, page 103.)

Bordeaux substitutes are more expensive and less efficient as fungicides than Bordeaux mixture, but cause less foliage injury. Consequently, by using higher concentrations, effective control of disease can be obtained with improved vigour of growth and increased crop yield. Improvement in yield which may amount to two or three tons per acre as compared with Bordeaux mixture is of far greater importance in the economy of tomato growing than is generally appreciated. The substitute compounds are easy to prepare and do not leave such conspicuous spray residues as Bordeaux mixture. Dilutions will vary with conditions, but, in general, 5 lb. to 100 gallons are required for outdoor spraying and 3 lb. to 100 gallons for glasshouse crops. Bordeaux substitute sprays can be combined with lead arsenate, D.D.T., Shirlan A.G. and nicotine sulphate. Soft soap should not be used. Where an activator for nicotine sulphate is required, 3 lb. hydrated lime should be added to the mixture.

Shirlan A.G.

A certified product containing 25 per cent. salicylanilide as a paste in water, plus wetting agent. It is used for protecting plants against attack by leaf-mould.

Shirlan A.G. at a dilution of 3 lb. to 100 gallons will hold leaf-mould in check and give improved crop yields. More effective control could be secured by using higher concentrations, but the cost of such treatments would not be justified by increase in yield.

Shirlan A.G. does not cause plant injury and can be combined with any of the copper sprays and with lead arsenate, D.D.T. and nicotine sulphate.

Insecticides

Lead Arsenate

Two types of lead arsenate are used as insecticides—acid lead arsenate and basic lead arsenate. Only the former is used on tomatoes. It is a white powder in which is incorporated sufficient wetting agent to make it easily wettable. Acid lead arsenate has been the standard insecticide for protecting plants against attack by caterpillars of various kinds, but is likely to be superseded by D.D.T.

The standard dilution is 3 lb. to 100 gallons, but against stem-borer up to 5 lb. to 100 gallons may be necessary.

Tomatoes are more resistant than most plants to damage from lead arsenate. When used in combination with Burgundy mixture, however, soluble arsenic is produced, resulting in plant injury, often of a severe type. Lead arsenate can be combined with copper sprays (other than Burgundy mixture), Shirlan A.G., D.D.T. and nicotine sulphate. It is inadvisable to combine soft soap with lead arsenate.

D.D.T.

This is coming into general use on tomatoes as a protective and eradicant spray against several pests. The active material, dichloro diphenyl trichlorethane, is prepared by manufacturers for spraying purposes in various forms. Wettable powders are most suitable for use by tomato growers, these being mixed with water in the same way as lead arsenate is normally prepared. There are two forms of D.D.T., but only one has high insecticidal value. It is necessary, therefore, that growers know the percentage content of active D.D.T. (i.e. the para para isomer as it is technically called) in a powder in order to calculate the correct dosage. Proprietary compounds do not always show this, except that certified compounds will always give the content of active D.D.T. in terms of the para para isomer on the label (see certification list, page 103).

Since different proprietary compounds vary in content of D.D.T., it is necessary in making recommendations as given in spray schedules (see page 89) to refer dilutions to the amount of active D.D.T. per 100 gallons. Growers will have to calculate the amount required of any particular powder on this basis. For example, if ½ lb. D.D.T. to 100 gallons is recommended, then with a proprietary powder certified to contain 25 per cent. active D.D.T. 2 lb. to 100 gallons will be required, and for a product containing 50 per cent. active D.D.T., 1 lb. to 100 gallons would have to be used.

D.D.T. is of outstanding merit in control of tomato-caterpillars, ½ lb. to 100 gallons being superior to lead arsenate at 3 lb. to 100 gallons. Trials have not been made in New Zealand against stem-borer, but it is likely to be highly effective against this pest. D.D.T. is also known to be of value in the control of thrips and white-fly. At present there is no information as to the likely effect of D.D.T. against tomato-mite.

Evidence suggests that excessive amounts of D.D.T. may adversely affect the growth of tomatoes. It is recommended, therefore, that concentrations should not exceed ½ lb. active D.D.T. to 100 gallons.

Providing growers take care to avoid spraying the ripening fruit closer than 7 days before harvest there will be no danger of exceeding the health tolerance of residue on the fruit.

D.D.T. wettable powders can be combined with safety with copper sprays, lead arsenate, Shirlan A.G. and nicotine sulphate. Chemical breakdown of D.D.T. can occur if mixtures which are alkaline, e.g. Bordeaux mixture or soft soap and nicotine sulphate, are left for long periods, twelve hours or more, before being applied to the plants.

In handling wettable D.D.T. powders, there is no greater risk to operators than occurs at present with lead arsenate.

Nicotine Sulphate

An oily liquid prepared from nicotine in a form which is less volatile than the nicotine itself. It is used as a contact insecticide for the eradication of sucking insects, principally green-aphis, thrips, white-fly, and tomato-mite.

In using nicotine sulphate it is necessary to make the mixture alkaline to bring about liberation of nicotine fumes. Soft soap is usually employed for this purpose, but where nicotine sulphate is combined with copper sprays or lead arsenate, hydrated lime is substituted for the soap.

The standard dilution is one gallon of nicotine sulphate to 800 gallons water (i.e. 1 pint to 100 gallons), plus 3 lb. of soft soap or hydrated lime per 100 gallons. Where thrips are to be controlled, the strength should be increased to 1 gallon to 600 gallons water (i.e. 1 pint to 75 gallons).

Nicotine Fumigation

Nicotine is also used for eradicating certain insects from tomato plants by fumigation in glasshouses. For this purpose the nicotine sulphate is volatilized by heat, using a metal container to hold the liquid supported over a small flame from a spirit lamp. For each 1,000 cubic feet of glasshouse space one fluid ounce of nicotine sulphate is used. It is advisable to have at least one fumigating unit to each 5,000 cubic feet of glasshouse space. The house should be made as air-tight as possible and treatment commenced in the late afternoon while the temperature is still high. The container holding the nicotine sulphate should be held just above the flame. The height of flame should be adjusted to give complete volatilization of the nicotine sulphate in approximately one hour. Next morning the house is opened and ventilated in the usual manner. Fumigation treatments are of value in propagation houses as a means of killing such insects as thrips and aphids, and in commercial glasshouses particularly for eradication of white-fly and tomato-mite.

Insect Baits

Paris Green or White Arsenic Bait

Bran	25 lb.
Paris green or white arsenic	1 lb.
Molasses	2 quarts
Water	approx. 3 gallons

Mix bran and poison dry; dissolve molasses in water and add to dry bran mixture until the bait becomes friable and crumbly. Avoid having bait too soggy and wet.

This bait is effective against cutworm and may also be used for the control of slugs, snails and slaters. It should be placed in small heaps on the ground near the base of plants or in the vicinity of boxes of young plants which are being damaged by slugs, snails or slaters.

Paris Green and Dried Blood Bait.

Dried blood	56 lb.
Paris green	1 lb.

Thoroughly mix the dried blood and Paris green.

The mixture is used for control of slaters, being broadcast over the soil at the rate of 1 oz. per square yard.

"Meta" or Metaldehyde Bait

Bran	28 lb.
"Meta" or metaldehyde	½ lb.

This bait is very effective against slugs and snails. The "Meta" (in powder form) is mixed with the bran and is used at the rate of 28 lb. per acre. It can either be broadcast dry or moistened with water so that it cakes somewhat when squeezed in the hand and when thrown out in handfuls makes little heaps on the ground. These heaps are spaced according to the damage occurring. The operation should be carried out in the evening. It is applicable in field and glasshouse. As substitutes for bran, materials such as flour, pollard, maize meal or brown bread crumbs may be used.

Dusts

Although dusts applied to tomato plants are, in general, less satisfactory than sprays for the control of diseases and pests, dehydrated copper sulphate dust applied to the soil surface gives good control of slugs and snails. Also a D.D.T. dust applied in the same way may be used for control of slaters.

Dehydrated Copper Sulphate Dust

Copper sulphate (bluestone)	1½ lb.
Hydrated lime	9 lb.

Heat copper sulphate over fire until it is reduced to a powder. Mix the powder with the lime and dust lightly over affected area after dark for control of slugs and snails.

D.D.T. Dust

A dust containing 5 per cent. active D.D.T. sprinkled in places frequented by slaters provides an effective control.

SPRAYING AND FUMIGATING SCHEDULES

SEEDLING PLANTS

Pest or Disease	Treatment	Remarks
Damping-off fungi (p. 14) Verticillium-wilt (p. 7) Foot-rot (p. 15) Tomato-canker (p. 23) Fusarium-wilt (p. 9)	Formalin 1 gal.–50 gal. water (p. 96) or chloropicrin 3–5 ml. per cubic foot (p. 97) or steam (p. 92)	Soil for seed-boxes and for transplanting should be treated as routine measure. Soil-boxes should also be treated.
Tobacco-mosaic (p. 35)	Steam (p. 92)	Soil for seed-boxes and transplanting should be treated wherever possible. Chemical treatments are not effective.
Eelworm (p. 69)	Chloropicrin 3–5 ml. per cu.ft. (p. 97) or D—D 3 ml. per cu.ft. (p. 99) or steam (p. 92)	Soil for seed-boxes and transplanting should be treated wherever experience has showed that infestation is likely to occur.
Late-blight (p. 4) Septoria-spot (p. 19)	Bordeaux 3–4–100 (p. 83) or Bordeaux substitute 3 lb.–100 gal. (p. 85)	Seedlings should be sprayed as soon as established after transplanting, again before hardening-off, and a third application before setting out in glasshouse or field.
Chewing insects, including caterpillars, weevils, etc. (pp. 56-63)	D.D.T. ½ lb.–100 gal. (p. 86) or lead arsenate 3 lb.–100 gal. (p. 85)	Spray seedlings during hardening-off and before setting out in the glasshouse or field.
Green-aphis (p. 68)	Nicotine sulphate 1 pint–100 gal. (p. 87) or fumigate with nicotine sulphate (p. 87)	Treatments only required when infestation is seen to occur.
Thrips as carriers of tomato spotted-wilt virus (p. 68)	Nicotine sulphate 1 pint–100 gal. (p. 87) or D.D.T. ½ lb.–100 gal. (p. 86), or fumigate with nicotine sulphate (p. 87)	Treatments required only where infection from spotted-wilt is suspected to occur from thrips infestation.

GLASSHOUSE CROPS

Pest or Disease	Treatment	Remarks
Verticillium-wilt (p. 7) **Fusarium-wilt** (p. 9) **Tomato-canker** (p. 23) **Foot-rot** (p. 15) **Sclerotinia-disease** (p. 9)	Steam (p. 92) or chloropicrin 3–5 ml. per sq. ft. (p. 97), or formalin 1 gal.–50 gal. water (p. 96)	Wherever possible treat soil annually.
Tobacco-mosaic (p. 35)	Steam (p. 92)	Treat soil where mosaic has appeared in the previous crop. Chemical treatments are not effective.
Eelworm (p. 69)	Chloropicrin 3–5 ml. per sq.ft. (p. 97) or D—D 3 ml. per sq.ft. (p. 99) or steam (p. 92)	Treat soil where infestation of previous crop has occurred.
Late-blight (p. 4) Septoria-spot (p. 19) Grey-mould (p. 12)	Bordeaux 3–4–100 (p. 83) or Bordeaux substitute 3 lb.–100 gal. (p. 85)	Apply as soon as plants are estabilshed and repeat at intervals of 14–21 days until danger of infection is past.
Leaf-mould (p. 17)	Shirlan A.G. 3 lb.–100 gal. (p. 85)	Apply as soon as plants are established and repeat at intervals of 14–21 days until plants are fully grown.
Stem-borer (p. 59)	D.D.T. ½ lb.–100 gal. (p. 86) or lead arsenate 3 to 5lb.–100 gal. (p. 85)	Apply as soon as plants are established in glasshouse where pest is known to occur. Spray the stems thoroughly and repeat at intervals of 14–21 days until plants are fully grown.
Chewing insects including caterpillars, weevils, etc. (pp. 56–63)	D.D.T. ½ lb.–100 gal. (p. 86) or lead arsenate 3 lb.–100 gal. (p. 85)	Apply as soon as plants are established and repeat at 14–21 day intervals until plants are fully grown.
Tomato-mite (p. 72) Green-aphis (p. 68) White-fly (p. 66)	Nicotine sulphate 1 pint–100 gal. (p. 87) or fumigate with nicotine sulphate 1 fluid oz. to 1,000 cu.ft. (p. 87)	Apply as soon as infestation is first seen. Repeat if necessary.
Thrips (p. 68)	Nicotine sulphate 1 pint to 75 gal., or fumigate with nicotine sulphate (p. 87) or spray D.D.T. ½ lb.–100 gal. (p. 86)	Apply only where pest occurs.

FIELD CROPS

Pest or Disease	Treatment	Remarks
Late-blight (p. 4) Septoria-spot (p. 19) Phoma-rot (p. 22)	Bordeaux 6–8–100 (p. 83) or Bordeaux substitute 5 lb.–100 gal. (p. 85)	Apply as soon as plants are established in the field and repeat at intervals of 10–14 days.
Stem-borer (p. 59)	D.D.T. ½ lb.–100 gal. (p. 86) or lead arsenate 3 to 5 lb.–100 gal. (p. 85)	Apply as soon as plants are established and repeat at intervals of 10–14 days until plants are fully grown.
Caterpillars (pp. 56–63)	D.D.T. ½ lb.–100 gal. (p. 86) or lead arsenate 3 lb.–100 gal. (p. 85)	Apply as soon as plants are established and repeat at intervals of 10–14 days until plants are fully grown.
Green-aphis (p. 68) Thrips (p. 68)	Nicotine sulphate 1 pint–75 gals. (p. 87) or D.D.T. ½ lb.–100 gal. (p. 86)	Apply only when infestation appears.

SOIL DISINFECTION

For control of soil-borne pests and diseases it is necessary that infection be eradicated from the soil before the crop is planted. Once the plants are growing there is no known treatment whereby infection can be eradicated without killing the plants. The principal methods used for disinfecting soils are by steam-heating and by chemicals. To obtain successful results from soil disinfection it is necessary to understand and apply certain general principles. These are discussed below. Soil disinfection is no guarantee against re-contamination. In some instances, disinfected soil is more readily reinfected than untreated soil. After treatment and until the crop is mature, care should be taken therefore to avoid re-introducing infection by such means as infected plants, cultivating implements or on workmen's boots. With propagating soil a common source of reinfection is the use of contaminated boxes.

It is necessary that steam or chemicals should have every chance to spread evenly and rapidly through the soil. To facilitate this the soil should be deeply and finely cultivated. Any added organic matter such as cover crop or straw should be worked into the soil and given a period of three to four weeks for partial decomposition before treating the soil. Soil moisture should be at the correct level to allow rapid heating or distribution of disinfectants. The correct moisture content can be judged by compressing a sample in the hand when it should retain its form without caking or soiling the hand.

Pre-treatment soil temperatures are important. For steam treatment, temperatures lower than 50° F. cause excessive condensation of steam with resultant pugginess of soil. For chemical treatments, temperatures should not be below 55° F. and preferably 65° F. or over, since lower temperatures slow down the rate of diffusion of the toxic gases.

Soil disinfectants are toxic to plants, consequently a period of aeration is necessary before planting. Actual periods are discussed later, but it should be remembered that where soil temperatures are low, longer periods are required to dissipate residual gases.

In disinfecting soil it should be remembered that the object is to kill harmful organisms without destroying all the beneficial bacteria and fungi. Excessive steam or chemical can therefore be definitely harmful to crop production.

STEAM DISINFECTION

Steaming of soil by low or high pressure is the most popular method of applying heat to the soil. The operation should be thorough and deep for the first time; subsequent operations need not be as thorough, but should be repeated every two to three years. The efficiency of treatments depends to a great extent on the choice of method. The temperature should be raised to 180–210° F. and maintained at that temperature for 10 to 20 minutes.

Low Pressure Steaming

A simple way of steaming small quantities of soil by low pressure is by using a copper. A piece of sheet iron perforated with quarter-inch holes is placed in the copper, so that it clears a gallon of water in the bottom. Soil, held in a sack, is placed in the copper over the supporting iron sheet. Water in the copper would boil in 10 to 15 minutes and the soil should reach a temperature of approximately 200° F. in 34 to 40 minutes, after which it can be turned out. A metal box equipped with a perforated false bottom could also be used.

High Pressure Steaming

Where high pressure steam is available it is possible to disinfect soil by placing it in a wooden framework, and applying steam by means of a grid of short, perforated pipes placed at the bottom of the soil layer, or by insertion of short spikes connected with the steam-hose. While steaming is in progress the soil should be covered with a lid, tarpaulin or sacking. Steam is passed until the soil temperature is approximately 200° F. and continued for 10 to 20 minutes.

Larger quantities of soil for seedling boxes can be placed in specially constructed bins and disinfected by application of high pressure steam. The side walls of these bins are of brickwork or concrete, the front and back, however, should be open to facilitate shovelling of the soil. Wooden or sheet-iron doors are fitted into slots left in the ends of the walls. The bin is filled with soil to a depth of 2 to 3 feet and covered with a tarpaulin or sacks. The concrete floor of the bin should have an overall fall of two inchres to allow for drainage of condensation water. A grid of $\frac{3}{4}$ in. pipes is fitted on the floor of the bin and connected with a $1\frac{1}{4}$ in. main steam pipe. The outer pipes of the grid are four inches out from the walls, and at eight inches centres over the rest of the floor. They are drilled with $\frac{1}{8}$ in. holes at 6 in. spacing along the top and between each of these one hole on either side. Holes should be drilled at different angles to ensure that steam emerges in many directions. Before use, all condensation water is cleared out of the pipe system with a small pressure of steam, after which the valves are closed until pressure is up in the boiler. A uniform temperature should be obtained throughout the soil, and if maintained for 20 to 40 minutes at 180° F. to 210° F. it gives satisfactory results. A head of steam at 60 lb. pressure is suitable for this method.

For steaming the soil in the glasshouse or out of doors, a boiler of 12 to 25 h.p. (preferably 20 h.p.) is required. A suitable boiler would provide a continuous supply of steam through a $1\frac{1}{2}$ in. pipe at a pressure of 70 to 80 lb. per square inch. The choice of a suitable layout rests with the grower, but the greater the distance the steam is brought, the larger the size of boiler required.

Steam Harrow

One of the most popular types of apparatus used by growers is the harrow. In this, the tines are attached to the lower surface of a combined inverted pan and steam chamber. The pan is 2 feet 8 inches square and made from

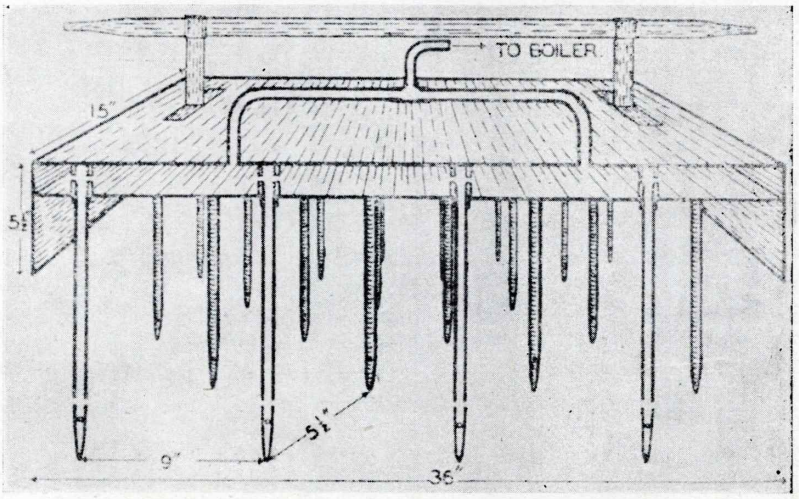

Fig. 84—Harrow for steam disinfection of soil.
After Cunningham.

heavy galzanized iron (Fig. 84), with a projecting 3 inch lip. The steam chamber is $1\frac{1}{2}$ in. deep, and the tines, 13 inches in length, are made of $\frac{3}{8}$ in. pipe, pointed at the end, and arranged in 6 rows of 7 tines. Each tine is perforated with three $\frac{1}{8}$ in. holes approximately 1 inch from the point. The harrows are operated in pairs. Steam emerging from ends of the spikes diffuses through the soil and is retained by the tray until the required temperature (180° F.) is secured at the necessary depth. Steam is passed through the soil for 10 to 15 minutes. After withdrawal of the harrow, the soil is covered with a tarpaulin or sacks.

The method described above may leave portion of the soil unheated, owing to obstructions such as foundations, posts and pipes. Another disadvantage is that disinfection is limited to 12 to 20 inches. Organisms surviving in untreated portions spread rapidly through the disinfected soil.

Hoddesdon Pipe System

A newer method is the Hoddesdon pipe system, which allows the heating of the entire volume of soil without handicap from obstructions. This system consists of a number of pipes of $1\frac{1}{4}$ in. internal diameter cut to desired lengths. One end of each pipe is closed with an iron plug; the other is

fitted with an elbow and connected with a vertical pipe two feet long. The horizontal pipe is provided with two lines of $\frac{1}{8}$ in. holes at 5 inch intervals drilled one on each side of the pipe and slightly towards the bottom. The shorter lengths of pipe stand up vertically in the soil during steaming and the top of the vertical pipe is fitted with an elbow and thread for hose coupling. Four of these pipes are joined by a connection consisting of three V pieces of $1\frac{1}{4}$ in. tubing joined together by Y unions. Steam from the main hose enters the connection at the base of the first V, passes along the two arms to two other V pieces, follows the two respective arms and passes through four lengths of flexible hose, which in turn are connected with the four

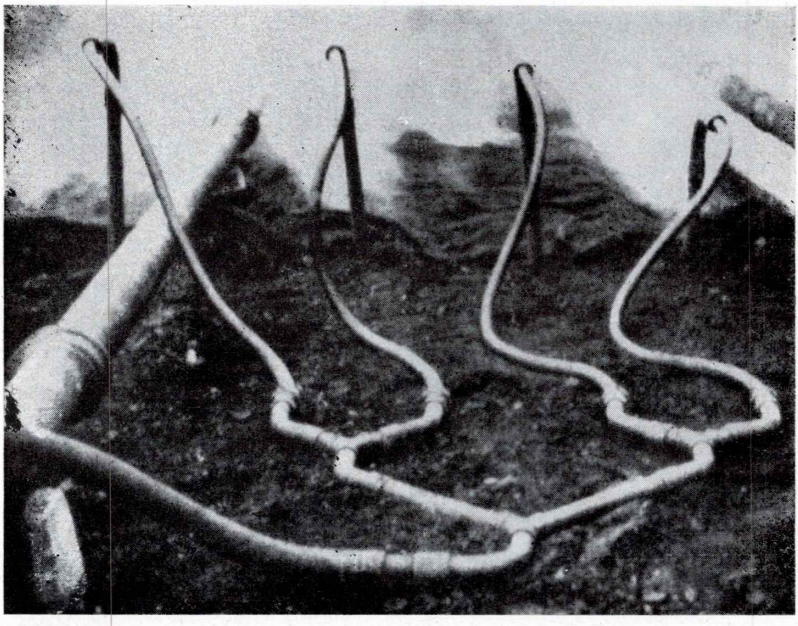

Fig. 85—Hoddesdon pipe system of steam disinfection in operation.
After Bewley.

vertical pipes (Fig. 85). This arrangement provides an even distribution of steam through the pipes. This method is applied in the following manner: A trench, 18 in. deep, is dug along one side of the area to be treated and the spoil is removed to the other side. The bottom of the trench should be loosened with a fork to facilitate penetration of heat. The first pipe is placed close to the wall, the next parallel to it 20 inches away. A second trench is dug, the spoil filling the first, and the same procedure is continued until four pipes, 20 inches apart, are laid in position and covered. The surface is now covered with sacks and four pipes are connected with the steam-hose. Another lot of four pipes is placed in position whilst steam is passed through the first four pipes. The operation is continued by pulling back the pipes

into successive trenches dug behind them. Each steaming covers an area of an approximate width of seven feet by the length of pipes and a sterilising temperature is obtained to a depth of at least two feet. The time necessary for steaming varies with the soil type and moisture content, but 15 to 25 minues are sufficient to raise the temperature to 200° F. and above. In this system the digging of soil is carried out simultaneously with steaming.

This method is suitable for all types of glasshouses, as the length of pipes can be altered to fit particular conditions. The pipes are easily removed, as they only need to be pulled back, and tramping on sterilised soil by workmen is therefore avoided.

Steam Disinfection of Boxes

Boxes used for potting soil should be disinfected by steam. A bin or a convenient container is filled to capacity with boxes and steam is applied either through a grid, a harrow or a steam-pipe, placed amidst the heap of boxes. The whole is covered with a tarpaulin and temperatures are taken until 180° to 200° F. are reached. This temperature is then maintained for 10 to 20 minutes. Boxes as well as soil in storage should be protected from re-infection.

CHEMICAL DISINFECTION

Heat treatment is the most satisfactory method of disinfection and the only one which can be used against tobacco-mosaic, but necessitates costly equipment. Chemical treatments have therefore been investigated and the most effective materials and methods of application are described below.

Formalin

Formalin is a solution containing a 36 to 40 per cent. formaldehyde gas dissolved in water to which a small amount of methyl alcohol has been added as a stabilizer. The fumes have a penetrating odour and irritate the nose and throat. Prolonged immersions in formalin solutions cause dryness and harshness of the skin. After prolonged storage or when exposed to the air, formalin solutions may become cloudy and form a white precipitate of paraformaldehyde.

Applied at the recommended rate, formalin gives satisfactory control of damping-off, verticillium-wilt, fusarium-wilt and other soil-borne fungous diseases. It does not control weeds and has little effect on eelworm. To secure effective results it is necessary to saturate the soil thoroughly with the solution, so that the formaldehyde fumes permeate all parts of the soil.

Fumes from formalin cause injury to vegetation and solutions should not be applied to soil in glasshouses in which there are living plants. Damage occurs if plants are set out in treated soil before all fumes have disappeared, but they may be set out with safety after 3 to 4 weeks, provided the soil is

aerated. Application of 1 in 50 formalin solutions cause injury when seed is sown at the time of application or shortly after. Seed can be sown safely in aerated soil 14 days after treatment.

The recommended strength of 1 in 50 solution is prepared by mixing one volume of formalin in 49 volumes of water. Formalin showing paraformaldehyde precipitate should not be decanted, but stirred well before dilution. If held in drums, these should be rolled to ensure thorough mixing. Where an appreciable amount of precipitate is present concentrations should be increased to 1½ or 2 in 50.

Potting soil in boxes is treated by application of a 1 in 50 solution at the rate of approximately 5 pints per cu.ft. of soil. After treatment, boxes should be stacked and the top layer covered with sacks saturated in the solution. Forty-eight hours later the boxes are spread out and left for aeration.

For treating glasshouse soil 50 gallons of a 1 in 50 solution are distributed over an area of 10 to 15 square yards. The following procedure is designed to give maximum distribution and penetration of the soil. A trench is dug at one end of the glasshouse and the soil is removed to the other end. The solution is applied to the bottom and walls of the trench, which is then filled with soil taken from the next trench. This soil and the trench just opened up are saturated with the solution and the operation is repeated until the whole area is treated. Spraying of the solution on the soil surface only may leave some infection in soil pockets which have remained unsaturated. Greater efficiency is obtained by covering the soil with sacks for a day or two after treatment.

The fumes disappear from the soil after a few days, but to assist this process it is advisable to aerate the soil by forking.

Solutions may be applied as a coarse spray with a watering-can or from a power spray outfit. In absence of the latter and in order to facilitate application it is advisable to provide wooden or metal tanks placed in an elevated position (either fixed in the glasshouse or mounted on a trolley), from which the solution can be distributed by gravity, using hose and nozzle.

Although not widely known in New Zealand, automatic devices are available on overseas markets in which the formalin concentrate is added directly to the water supply.

Formalin Disinfection of Boxes

Boxes may be satisfactorily disinfected against fungous and bacterial diseases by dipping them in a 1 in 50 solution of formalin for 5 minutes. Prior to dipping, boxes should be thoroughly cleaned.

Chloropicrin

Chloropicrin is a heavy colourless liquid which when exposed to sunlight turns yellow, but without affecting its performance. It vaporizes into a pun-

gent gas which causes smarting and watering of eyes and, when inhaled, violent attacks of coughing. One pound of chloropicrin contains 273 ml., i.e. approximately $9\frac{1}{2}$ fluid ounces.

When injected into the soil it changes into a gas, which spreads readily, permeating through the soil to a distance of 5 to 8 inches from the point of injection. The high volatility of the chemical ensures upon aeration complete disappearance of all traces of chloropicrin. It is not inflammable in either the liquid or gaseous state. Chloropicrin should be stored in a cool place, but when about to be used it can be handled safely under all weather conditions. It decomposes corks and rubber stoppers, therefore bakelite or metal screw-top containers should be used for storing the liquid. The tear-gas effect safeguards the user from exposure to concentrations which may become detrimental to his health. If the liquid is spilled on the skin or clothing, the affected parts should be washed immediately with soap and running water. If this precaution is not observed, blistering of more sensitive parts of the skin may occur. Chloropicrin can be handled without danger if one manipulates with it down wind and avoids exposing or spilling the liquid.

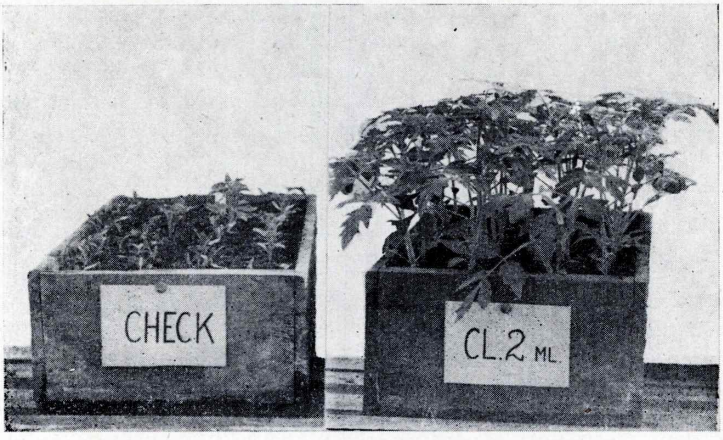

Fig. 86—Chloropicrin treatment: Tomato plants growing in soil heavily infested with eelworm.
Left: Untreated. Right: Treated with 2 ml. chloropicrin per cubic foot.
Photo by L. H. Wright.

Chloropicrin gives satisfactory control of eelworm, verticillium-wilt, damping-off diseases, etc., and reduces weed populations. Soils treated with chloropicrin give a definite increase in plant growth (Fig. 86) which is due partly to reduction of plant diseases and pests, and partly to improvement of the nutrient condition.

Potting soil can be treated satisfactorily when placed in drums, barrels or tight boxes which are subsequently covered with wet sacks or a tarpaulin. The injection of chloropicrin directly into seedling boxes is not satisfactory.

Quantities required for the fumigation of composted soil or ordinary soil are 3 to 5 ml. per cu.ft. respectively. For soils treated in bulk the fumigant should be applied by injection into holes made at different depths to ensure equal distribution. A graduated burette which is readily available on the market can be used for measuring out quantities (Fig. 87). Covers should be removed from fumigated soil after 48 hours and the soil forked over for aeration. Treatment of soil with chloropicrin does not alter its physical structure and leaves no toxic residues. Planting can be carried out 7 to 14 days after treatment, and in warm weather soil which has been thoroughly aerated can be used as soon as 5 days after treatment. In heavy soils residual fumes may last longer owing to the adsorptive property of clay particles.

For disinfection of soil *in situ* in glasshouses or out of doors, chloropicrin is injected at a depth of 4 to 6 inches, injections being spaced 10 to 12 inches apart. Quantities to be injected vary from 3 to 5 ml. per sq.ft. (i.e. 1 lb. to 6 to 10 square yards), according to soil type and severity of infection. The fumigant can be applied by means of an injector of the type shown in Fig. 88.

To avoid the unpleasant effect of fumes which may escape from the ground it is advisable to wet the top half inch of soil before treatment and to fill in injection holes as treatment progresses. An additional watering is required after fumigation, applied by sprinkling 1 gallon of water per square yard of soil surface.

Doors and vents in the glasshouse should be opened during application, but closed for 48 hours afterwards. The soil should be forked over for aeration and can be planted 14 days after treatment. It is safe to plant when the characteristic odour of the gas cannot be detected in a sample of soil taken from a depth of 4 to 6 inches. Because of its toxic effects, chloropicrin should not be used in proximity of living plants.

D–D

D–D is an oily, dark-coloured, volatile liquid with a strong, nauseating smell. It consists of a mixture of dichloropropane and dichloropropene, formed as a by-product in the refining of petroleum oils. There are two different qualities of D–D, a crude form containing 75 per cent. of the mixture plus impurities, and a pure form which is a 50 : 50 mixture of compounds. One pound of the pure form contains 380 ml. (i.e. approximately 13½ fluid ounces). Applications of the pure form only are here discussed.

D–D is very effective in controlling eelworm and soil-borne pests. In potting soil treated in air-tight containers it ensures a 60 per cent. reduction of damping-off and wilt diseases and kills 30 per cent. of the weed population. Application of D–D does not alter the physical structure of the soil, and crop yields are increased through reduction of harmful organisms (Fig. 89).

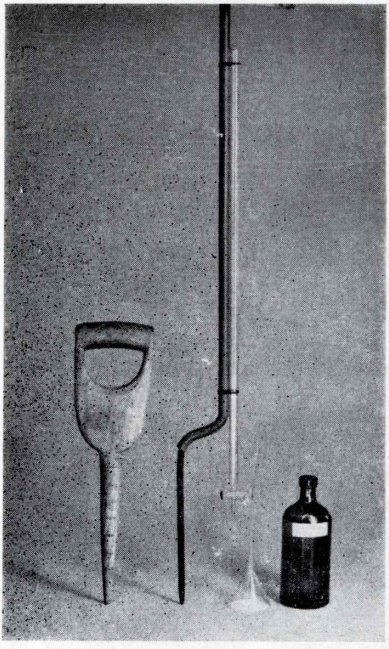

Fig. 87—Soil fumigation: a graduated burette of 50 ml. capacity attached to metal stand which serves as support when the flow is directed into holes dibbled in soil. A dibble and funnel are also shown.

Photo by L. H. Wright.

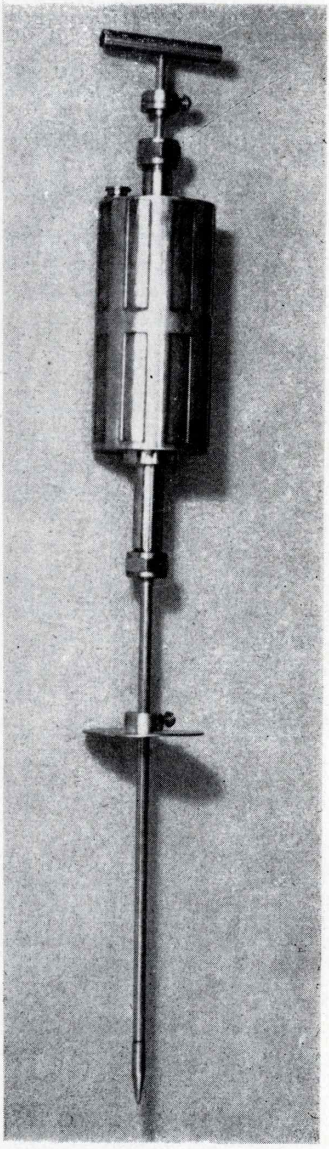

Fig. 88—Soil fumigation: soil injector designed by the Plant Diseases Division.

Photo by L. H. Wright.

One application of D–D often ensures good crops for more than one season. However, the lasting effect of the fumigant, as well as dosage rates and the period of aeration before planting, depend largely upon soil conditions and type and virulence of pests and diseases. D–D is effective for this purpose, not very unpleasant to handle, and is economical in use. Methods of application to potting soil and soil *in situ* are similar to those described for chloropicrin. Precautions and storage conditions are also the same. A period of 3–4 weeks is required after treatment before planting. Because of its lower volatility the water seal as required for chloropicrin is not essential.

Fig. 89—Soil fumigation with D—D: plants on right showing increased growth following treatment of eelworm-infested soil.

Photo by L. H. Wright.

COST OF TREATMENTS

Relative costs of soil treatments at present and methods of application are given in Table I.

TABLE I.

RELATIVE COSTS OF MOST EFFECTIVE SOIL TREATMENTS AND THEIR EFFICACY IN CONTROL OF DISEASES, PESTS AND WEEDS.

Method.	Where materials obtainable.	Dosage per sq. ft. (ml.)	Cost of application per 1,000 sq. ft. (£ s. d.)	Safety period before planting (weeks).	Approximate degree of efficacy.			
					Wilt Diseases.	Damping-off.	Eelworm.	Weed Control.
Steam harrow (using 2 harrows simultaneously for 10 minutes)			6 17 0*	3–4	Very good	Very good	Very good	Very good
Hoddesdon pipe			6 3 0**	3–4	„ „	„ „	„ „	„ „
Formaline	N.Z. Frtgrwrs. Fed. Ltd.	33.6	4 10 0***	2–4	Good	Good	Poor	Poor
Chloropicrin	„ „	3.0	5 16 0***	1–2	„	„	Good	Fair
D–D	Shell Co. of N.Z. Ltd.	3.0	1 2 0***	2–4	Fair	Fair	„	Poor

* Including cost of labour, coal, electric current for stoker, water, 5 per cent. interest on investment and 12 per cent. depreciation of installations.

** As above, plus cost of fuel and 4 per cent. depreciation of a Graveley tractor.

*** Including cost of material, labour and water.

CERTIFICATION OF THERAPEUTANTS*

By G. H. CUNNINGHAM, Director,

Plant Diseases Division, Plant Research Bureau,
Department of Scientific and Industrial Research.

OUR work of improvement in methods of combating bacterial, fungous and insect diseases and pests of plants has shown the necessity for assessing the value of the many sprays, dusts, fumigants, etc.—collectively termed therapeutants—placed on the New Zealand market. Tests carried out during the past years have demonstrated that of these, quite half were ineffectual for the purpose for which they were sold. It is apparent, therefore, that orchardists, nurserymen and farmers should be provided with some simple means whereby they are enabled to procure only efficient materials.

To this end the Plant Diseases Division has introduced the Certification of Therapeutants, operated on the following lines:—

†(1) The manufacturer of the therapeutant (or his agent) offers to the Division for certification samples of those products he wishes to place upon the New Zealand market. Accompanying his application are particulars regarding its composition, methods of analysis (where necessary) and evidence showing it is worthy of test. Such information is treated as confidential by the Division.

(2) Products are then tested in the laboratory and field under rigorously controlled conditions. Tests are mainly biological, although chemical and/or physical analyses are made to check the composition of different samples of the same product. In addition are ascertained the most efficient concentrations at which the product is safe to apply to plants and yet will give most effectual control of diseases or pests.

(3) If the therapeutant passes the tests imposed, it is certified and the manufacturer (or his agent) supplied with a *Warrant of Certification*. This is to be incorporated in or on the label of the product, since it bears the registered trade mark and also the purposes for and concentrations at which it may be used. The product is also listed in the *Certification Lists,* published in July and January of each year and distributed to all users of therapeutants on a commercial scale. Orchardists, nurserymen and farmers may therefore purchase any certified product with confidence, knowing that it is efficient for the purpose for which it is offered for sale in the Dominion.

Plant Diseases Division.

* Supplement to *"The Orchardist of New Zealand,"* September 6, 1948.

† Detailed particulars are supplied in Plant Diseases Division Form No. 1—Certification of Therapeutants—which may be procured from the Director, Plant Diseases Division, Private Bag, Auckland.

CERTIFICATION OF THERAPEUTANTS

Twenty-third List, July, 1948.

The publication of this cancels all previous lists.

* Trade Name of Product.	Manufacturer or Agent.	Purpose.	† Remarks.
	ACID LEAD ARSENATE		
"Blue Bell"	N.Z. Fruitgrowers' Federation, Ltd., Wellington, New Zealand, Agents.	Control of chewing insects.	Apply at rates of 1 lb. per 100 gallons on stone fruits, 1½ to 2 lb. per 100 gallons on apples and pears and 2½ to 3 lb. per 100 gallons on tomatoes.
"Cooper's"	Imperial Chemical Industries (N.Z.), Ltd., Wellington, New Zealand.		
"Cooper's Arsinette"	Wm. Coper and Nephews (Aus.), Ltd., Sydney, Australia.		
"Lunvale"	Imperial Chemical Industries (N.Z.), Ltd., Wellington.		
"Lunvale Arsinette"	Imperial Chemical Industries (N.Z.), Ltd., Wellington.		
"Orchard Brand"	Ivory Bros., Ltd., Wellington, New Zealand.		
"Ortho"	Ivory Bros., Ltd., Wellington, New Zealand.		
"Vallo"	Imperial Chemical Industries (N.Z.), Ltd., Wellington, New Zealand.		
	BASIC LEAD ARSENATE		
"Niagara"	N.Z. Fruitgrowers' Federation, Ltd., Wellington, New Zealand Agents.	Control of chewing insects.	Apply at the rate of 2 lb. to 3 lb. per 100 gallons.
"Ortho"	Ivory Bros., Ltd., Wellington, New Zealand.		

* Trade Name of Product.	Manufacturer or Agent.	Purpose.	† Remarks.
	COLLOIDAL SULPHUR		
"Colsul 25"	The Fruitgrowers' Chemical Co., Mapua, Nelson, New Zealand.	Control of black-spot and powdery mildews.	Apply at concentrations of 3 lb. per 100 gallons when combined with lime sulphur or 5 lb. when used alone.
"Colsul 40"	The Fruitgrowers' Chemical Co., Mapua, Nelson, New Zealand.		Apply at concentrations of 2 lb. per 100 gallons when combined with lime sulphur or 3 lb. when used alone.
"Ialine"	Burt, Boulton & Haywood, Ltd., London, England.		Apply at concentrations of 1½ lb. per 100 gallons when combined with lime sulphur or 2½ lb. when used alone.
	COPPER COMPOUNDS		
"Cuprox"	Imperial Chemical Industries (N.Z.), Ltd., Wellington, New Zealand.	Control of late-blight of tomatoes and potatoes, septoria-spot of celery and ring spot of lettuce.	Apply at concentrations of 5 lb. per 100 gallons.
"Oxi-cop"	Elliotts and Australian Drug Pty., Ltd., Balmain, New South Wales, Australia.		Apply at concentrations of 3 lb.–5 lb. per 100 gallons.
"Perenox"	Imperial Chemical Industries (N.Z.), Ltd., Wellington, New Zealand.	Control of late-blight of tomatoes.	

* Trade Name of Product.	Manufacturer or Agent.	Purpose.	† Remarks.
		COPPER SULPHATE	
"Te Papapa"	The New Zealand Farmers' Fertilizer Co., Auckland, New Zealand.	Preparation of Bordeaux mixture.	Purity of 98% to 99%.
		DICHLORO-DIPHENYL-TRICHLORETHANE (D.D.T.) DUSTS	
D–Dust No. 1	The Fruitgrowers' Chemical Co., Mapua, Nelson, New Zealand.	Control of chewing insects on vegetable crops. Apply at 10 to 25 lb. per acre according to size of plants.	1.0% para para isomer.
D–Dust No. 2	The Fruitgrowers' Chemical Co., Mapua, Nelson, New Zealand.		2% para para isomer.
"Pespruf 2"	Imperial Chemical Industries (N.Z.), Ltd., Wellington, New Zealand.		1.5% para para isomer.
		DICHLORO-DIPHENYL-TRICHLORETHANE (D.D.T.) WETTABLE POWDERS	
"D–Spray 25"	The Fruitgrowers' Chemical Co., Mapua, Nelson, New Zealand.	Control of chewing insects on vegetable crops.	25% para para isomer. Apply at concentration of 1 to 4 lb. per 100 gallons.
"D–Spray 50"	The Fruitgrowers' Chemical Co., Mapua, Nelson, New Zealand.		50% para para isomer. Apply at concentration of ½ to 2 lb. per 100 gallons.
"Pespruf 50"	Imperial Chemical Industries (N.Z.), Ltd., Wellington, New Zealand.		

* Trade Name of Product.	Manufacturer or Agent.	Purpose.	† Remarks.
	NICOTINE SULPHATE		
"Black Leaf 40"	F. Cooper, Ltd., Wellington, New Zealand, Agents.	Control of sucking insects.	Apply at rate of 1 pint in 75 or 100 gallons.
	ORGANIC SEED-DUST COMPOUNDS		
"Agrosan G.N."	Imperial Chemical Industries (N.Z.), Ltd., Wellington, New Zealand.	Control of cereal smuts and stripe disease.	Apply a seed dressing at rate of 2 oz. per bushel.
"Spergon"	Tanner Bros., Ltd., Wellington, New Zealand.	Control of pre-emergence damping-off of peas.	Apply a seed dressing at rate of 2 oz. per bushel.
	POLYSULPHIDE SULPHURS Lime Sulphur		
"Lawrys"	W. L. Lawry, Stoke, Nelson, New Zealand.	Control of fungous diseases and sucking insects.	Polysulphide content of 15%.
"Polysul"	The Fruitgrowers' Chemical Co., Mapua, Nelson, New Zealand.		
"Te Papapa"	The New Zealand Farmers' Fertilizer Co., Auckland, New Zealand.		
	SALICYLANILIDE		
"Shirlan A.G."	Imperial Chemical Industries (N.Z.), Ltd., Wellington, New Zealand.	Control of leaf-mould of glasshouse tomatoes.	Apply at concentrations of 3 lb. per 100 gallons.

* Trade Name of Product.	Manufacturer or Agent.	Purpose.	† Remarks.
	SPRAYING OILS		
	Summer ("White") Oils.		
"Avon Emulsifine" "Gargoyle White" "Shell White-" "Sprayol White" "Volck 96 Medium"	Tide Water Associated Oil Co., San Francisco, United States of America. Vacuum Oil Company Prop., Ltd., Wellington, New Zealand. Shell Company of New Zealand, Ltd., Wellington, New Zealand. The Fruitgrowers' Chemical Co., Mapua, Nelson, New Zealand. Ivory Bros., Ltd., Wellington, New Zealand, Agents.	Control of sucking insects.	Apply at concentrations of 1% on apples and 3% on citrus.
	Winter ("Red") Oils.		
"Avon Emulsifine" "Gargoyle Red" "Gargoyle Winter Spray Emulsion" "Shell Palespray" "Shell Red Spray" "Sprayol Red" "Winter Volck"	Tide Water Associated Oil Co., San Francisco, United States of America. Vacuum Oil Company Prop., Ltd., Wellington, New Zealand. Vacuum Oil Company Prop., Ltd., Wellington, New Zealand. Shell Company of New Zealand, Ltd., Wellington, New Zealand. Shell Company of New Zealand, Ltd., Wellington, New Zealand. The Fruitgrowers' Chemical Co., Mapua, Nelson, New Zealand. Ivory Bros., Ltd., Wellington, New Zealand, Agents.	Control of sucking insects in dormant season.	Apply at concentration of 4% to 5%.

* Products are arranged alphabetically, consequently the sequence in which they are presented does not imply any order of merit.

† Concentrations vary according to the disease to be controlled and the susceptibility of the host plant to spray damage. Reference should be made to the local Orchard or Agricultural Instructor of the Department of Agriculture for additional information in the use of those materials.

A KEY TO TOMATO DISEASES AND PESTS

I. Plants wilted:

A. *Decay or discolouration of stems, or discolouration of vascular tissues—*

1. Vascular tissues light-brown . . . . . *Verticillium-wilt* (p. 7)
2. Vascular tissues and pith dark-brown, stems shrunken . . . . . *Tomato-canker* (p. 23)
3. Vascular tissues light-brown, stem decay at base . . *Fusarium-wilt* (p. 9)
4. Light-brown areas on stems, black bodies in pith . . *Sclerotinia-disease* (p. 9)
5. Greyish-brown areas on stems, with grey mould growth on surface . . . . . *Grey-mould* (p. 12)
6. Young plants, stems shrivelled at ground-level . . *Foot-rot* (p. 15)
7. Seedling plants, stems decayed at ground-level . . *Damping-off* (p. 14)

B. *No decay of stem or discolouration of vascular tissues—*

1. Tunnels in lower portion of stem, small pink caterpillars present . . . . . *Stem-borer* (p. 59)
2. Stems of young plants eaten through at ground-level, plump grey caterpillar in soil . . . . *Cutworm* (p. 61)
3. Roots destroyed—
   (*a*) white grubs with brown heads in soil, grubs lying in form of "U" . . . . . *Grass-grub* (p. 63)
   (*b*) limp caterpillars 1½-4 in. long in soil burrows *Subterranean grass-caterpillar* (p. 63)
   (*c*) tough, cream to dark-brown, worm-like grubs in soil . . . . . *Wireworm* (p. 63)
4. Young plants, leaves whitened or silvered, red-legged mites present . . . . . *Red-legged earth-mite* (p. 74)
5. Numerous small, white insects on leaves . . *White-fly* (p. 66)

II. Leaf symptoms:

A. *Spots small, numerous, usually less than ¼-inch diameter—*

1. Spots grey, brown margins with black specks in centre . . . . . *Septoria leaf-spot* (p. 19)
2. Minute, dry, rough spots with narrow yellow halos *Tomato-speck* (p. 25)
3. Irregular brown or bronze spots, rapid death of leaves . . . . . *Tomato spotted-wilt* (p. 28)
4. Irregular brown spots, mottling and curling . . *Severe tomato-streak* (p. 41)

B. *Spots large—*

1. Buff-coloured, velvety spots on lower leaf surfaces *Leaf-mould* (p. 17)
2. Irregular dark-brown areas with zonate markings *Phoma-rot* (p. 22)
3. Dark areas of dead tissue, associated with dark streaks on leaf stalks . . . . . *Tomato-streak* (p. 39)
4. Irregular black areas affecting part or whole of leaf, sometimes white downy growth on under-surface . . . . . *Late-blight* (p. 4)

C. *Spots diffuse—*

1. Diffuse bronzing . . . . . *Tomato spotted-wilt* (p. 28)
2. Diffuse bronzing with fawn-coloured dust present *Tomato-mite* (p. 72)
3. Silvering or whitening, red-legged mites present . . *Red-legged earth-mite* (p. 74)

D. *Leaves mottled, curled and malformed—*

1. Inward curling, with green-aphids present . . *Green-aphis* (p. 68)
2. Young leaves distorted; green, shield-shaped insects ($\frac{1}{2}$-in. long) present on plant or under debris . . *Green vegetable-bug* (p. 65)
3. Light and dark-green mottling, puckered surface *Tobacco-mosaic* (p. 35)
4. Foliage pale, tinted blue, leaflets slightly rolled . . *Tomato spotted-wilt* (p. 28)
5. Leaves narrow, rolled, with pointed lobes . . *Cucumber-mosaic* (p. 32)
6. Extreme narrowing, veins prominent and paralleling midrib . . . . . *Hormone weedkiller-injury* (p. 48)
7. Downward twisting of leaf stalk; dark scabby streaks on under sides near base . . . . *Leaf-twist* (p. 54)

E. *Holes eaten in leaves—*

1. Green, pink or brown caterpillars up to $1\frac{1}{2}$ inches long present . . . . . *Caterpillars* (p. 56)
2. Slime trails present, only young plants attacked . . *Slugs and snails* (p. 76)
3. Small pieces eaten, young plants only, slaters present under boxes or debris . . . . *Slaters* (p. 77)
4. Crowns eaten out of young plants, green or grey legless grubs or weevils in or on soil at base . . *Vegetable-weevil* (p. 62)

III. Stem symptoms:

A. *Stems bronzed—*

1. Diffuse bronzing with fawn-coloured dust . . *Tomato-mite* (p. 72)

B. *Superficial dark areas or streaks—*

1. Dark-brown to black areas, also on leaf stalks . . *Late-blight* (p. 4)
2. Long dark streaks, also on leaf stalks . . . . *Tomato-streak* (p. 39)
3. Short dark streaks, also on leaf stalks, associated with distortion of leaves . . . . . *Severe tomato-streak* (p. 41)
4. Long dark streaks, also on leaf stalks, associated with bronzing or spotting of leaves . . . . *Tomato spotted-wilt* (p. 28)

C. *Localised shrunken or shrivelled cankered areas—*

1. Light-brown decayed areas, pith white with black bodies embedded . . . . . *Sclerotinia-disease* (p. 9)
2. Light-brown decayed areas at base . . . . *Fusarium-wilt* (p. 9)
3. Greyish-brown areas, grey mould growth on surface *Grey-mould* (p. 12)
4. Brown areas with longitudinal splits, pith dark-brown . . . . . *Tomato-canker* (p. 23)
5. Light-brown discolouration and shrivelling at ground-level, only on young plants . . . . *Foot-rot* (p. 15)
6. Light-brown decay at ground-level, collapse of plants, only on seedlings . . . . . *Damping-off* (p. 14)

D. *Stems eaten—*

1. Tunnels in lower portion of stem, small pink caterpillars present .. .. *Stem-borer* (p. 59)
2. Young plants cut off at ground-level, plump grey caterpillar in soil .. .. *Cutworm* (p. 61)
3. Small pieces eaten, young plants only, slaters present under boxes or debris .. .. *Slaters* (p. 77)

IV. Root symptoms:

A. *Roots eaten—*

1. White grubs with brown heads in soil, grubs lying in form of "U" .. .. *Grass-grub* (p. 63)
2. Limp caterpillars 1½-4 in. long in soil burrows .. *Subterranean grass-caterpillar* (p. 63)
3. Tough, cream to dark-brown, worm-like grubs in soil .. .. *Wireworm* (p. 63)

B. *Nodules on roots—*

1. Small smooth nodules distributed over roots .. *Root-eelworm* (p. 69)
2. Large spherical, wrinkled galls on main roots .. *Crown-gall* (p. 27)

C. *Roots decayed—*

1. Smaller roots rotted, dark areas on main roots .. *Fusarium-wilt* (p. 9)
2. Light-brown decay of main roots on young plants only .. .. *Foot-rot* (p. 15)

V. Fruit symptoms:

A. *Fruit spots—*

1. Small, light-brown, rough, raised pustules with white halos .. .. *Tomato-canker* (p. 23)
2. Very small, brown-black slightly raised pustules with faint halos on ripened fruits .. .. *Tomato-speck* (p. 25)
3. Dark-brown, depressed, smooth spots up to ⅛ in. diameter .. .. *Tomato-streak* (p. 39)
4. White, circular, superficial ring spots .. .. *Water-spot* (p. 13)

B. *Fruit rots—*

1. Dark-brown, firm, irregular, wrinkled areas, over large portions of fruits .. .. .. *Late-blight* (p. 4)
2. Dark, depressed bands, fruits wrinkled .. .. *Tomato-streak* (p. 39)
3. Greyish-green areas, soft, with grey mould on surface .. .. *Grey-mould* (p. 12)
4. Dark brown-black, circular, firm, depressed areas, with small black pustules in centre .. .. *Phoma-rot* (p. 22)
5. Dark-brown, circular, depressed, smooth, tough areas at blossom end .. .. .. *Blossom-end rot* (p. 44)
6. Yellow or white, flattened, smooth, dry, papery areas, on sides of fruit exposed to sun .. .. *Sunscald* (p. 51)

C. *Fruit surfaces mottled or blemished—*

1. Light-red or yellow, well defined, zoned areas on ripe fruit . . . . . *Tomato spotted-wilt* (p. 28)
2. Pronounced red and yellow mottling, areas with diffuse margins . . . . . *Severe tomato-streak* (p. 41)
3. Blotches on fruit, dark-green on green fruit, pale on ripe fruit. Dark network below surface . . *Blotchy-ripening* (p. 46)
4. Dark-green areas at stem end on green and ripening fruits. Underlying tissues and core hard . . *Hard-core* (p. 47)
5. Light-grey, corky, cracked blemishes on skin . . *Thrips-injury* (p. 68)
6. Bronze, roughened blemishes on skin. Fawn dust on surface . . . . . *Tomato-mite* (p. 72)
7. Bronze blemishes on green fruits. Skin not roughened . . . . . *Tomato spotted-wilt* (p. 28)
8. Diffuse mottling, green shield-shaped insects present . . . . . *Green vegetable-bug* (p. 65)

D. *Fruit malformed—*

1. Fruits slightly flattened, small and of light weight *Cucumber-mosaic* (p. 32)
2. Fruits elongated, beaked and hollow . . . . *Hormone weedkiller injury* (p. 48)
3. Fruits puffy, soft and flabby. Internally, pockets present . . . . . *Pockets* (p. 52)
4. Pronounced puckering at blossom-end. Depressions sometimes lined with rough scar tissue . . . . *Catface* (p. 51)
5. Fruits distorted, with dark, depressed, scabby areas, on any part of fruit . . . . . *Tomato-streak* (p. 39)

E. *Fruits cracked or eaten—*

1. Cracking of fruit at stem end, cracks radial or forming concentric rings . . . . . *Growth-cracks* (p. 50)
2. On young fruits, splits on side or blossom end exposing seeds . . . . . *Fruit-splitting* (p. 53)
3. Holes eaten in fruit, caterpillars present . . *Caterpillars* (p. 56)

VI. Seedling disease:

1. Stems decayed at ground-level . . . . *Damping-off* (p. 14)
2. Failure of seedlings to emerge, seedlings decayed in soil . . . . . *Damping-off* (p. 14)